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VOLUME 59
No. 8

MECHANICAL ENGINEERING

AUGUST
1937

GEORGE A. STETSON, *Editor*

Jobs of Mechanical Engineers

TO YOUNGER readers especially is commended the paper which James Ellis presents elsewhere in this issue on the work of mechanical engineers in chemical plants. It was learned long ago that the electrical industry's manufacturing problems are principally within the field of mechanical engineering. To a greater or less extent this is also true of the chemical and other process industries.

While it is natural to think of certain traditional fields of endeavor for the occupation of mechanical-engineering graduates, sight must not be lost of new and more numerous possibilities. Mr. Ellis' paper suggests opportunities in chemical plants. Readers who are familiar with other kinds of work in which mechanical engineers can find profitable employment and render needed services are invited to write about them for our correspondence pages.

Men Make Research

ANDREW KEOGH, Yale librarian, has been known to remind admiring groups that stand in front of the magnificent Sterling Library in New Haven that "the library is inside." As with libraries, so also it is with research institutions; and the architectural splendor of the new home of the Mellon Institute in Pittsburgh should not blind us to the fact that the laboratory and the men who accomplish research results are inside.

Dr. E. R. Weidlein, director of the Institute, voiced a variation of this thought at the dedicatory exercises in May. He said:

"The Institute has become a guild of scientists. Here are gathered many men trained in chemistry, biology, physics, and engineering. They help one another directly; and even more important, they create an atmosphere of achievement for themselves in which there grow vision and determination for thorough, careful work. Their success is not accidental. It is the outcome of strong minds and of orderly thought, of good will and of good teamwork, of seeking toward a great end."

Not all research, to be sure, is carried on under these favorable conditions. Many an inquiring intellect labors under the handicap of lack of funds and facilities but with the most important of all attributes, the intelligence, the enthusiasm, and the determination to do the best that is possible under existing conditions, and the results are frequently epoch-making.

Research has become a respectable and a popular field of activity. It is known to pay attractive dividends in profits and fame. Industrial and educational institutions have come to feel that they must participate in it, and not always wisely. Stimulation by opportunists, seeking publicity and endowments rather than a desire for knowledge and sound results, is not enough.

Industrial research is in its infancy. Upon it the progress of the future depends. Industries not yet awakened to its possibilities must turn to it for help sooner or later. When they do so intelligently they will find men in educational institutions and in their own ranks or those of other industries to whom they can look for help. The result, if a proper program is followed with intelligence and determination, will be helpful to themselves and to humanity. Above all, men make research.

The "A.S.M.E. Library"

WHEN The American Society of Mechanical Engineers became one of the Founder Societies at the time the Engineering Societies Building in New York was provided through the munificence of Andrew Carnegie, its collection of books was merged with those of the other societies in the Engineering Societies Library. Losing thus its identity as an individual Society venture it gained in bulk, prestige, and opportunities for service in the merger and became part of the finest engineering library in this country, if not in the world. Today this library has a collection of 140,287 volumes, 7268 maps, and 4298 "searches," bibliographies compiled by its staff at the request of clients, and a catalog representing a net total of 151,512 items. Through gifts it has become the depository of various collections of rare books. Its shelves are filled with the current and bound issues of practically every periodical of engineering importance published anywhere in the world. Through purchase and the generosity of publishers of technical books it augments its accessions of engineering literature at slight expense; for example from Sept. 30, 1936, to April 30, 1937, gifts totaled 1040 and purchases only 196 volumes and maps.

In addition to its service as a reference, and to a limited extent a lending, library, and as a reading room, the Engineering Societies Library provides, at modest cost sufficient to cover expenses, translations of articles in foreign languages, photoprints of original articles in its collection, and bibliographies specially prepared, follow-

ing an estimate of cost by the library staff, for concerns and individuals requiring such services. From Sept. 30, 1936, to April 30, 1937, no less than 1498 individuals and concerns were so served with 69 searches and copies of searches, 54 translations, and 11,049 photoprints. In 1935–1936, 3013 letters were written and 5072 telephone calls were answered in connection with this service. Thus it is clear that the library is a national institution and its usefulness to the individual is not limited by his inability to visit it frequently in person.

But this common depository of the books and periodicals that make up the literature of engineering has other uses than those enjoyed by individuals. Upon these collections and reference works the editorial staffs of the Founder Societies rely in their daily work. For example, every bibliographical reference found in papers published by the A.S.M.E. is checked in the library for accuracy and completeness—and it is a sad commentary on the fallibility of authors that only a few complete and accurate references are discovered. What this service means to those who must rely upon these references need not be emphasized here.

What does library service cost? A recent report of a special committee says: "The average member's contribution through his society for the support of the library in 1935–1936 was just under 61 cents. The highest was 85.5 cents, for the A.I.M.E., and the lowest 57.8 cents for the A.S.M.E." Is 58 cents per year per member too much to pay for this service, direct, indirect, or potential as it may be in the individual case? The library needs more money. It is preparing to publicize its needs in an endeavor to create a favorable disposition on the part of every member toward these needs. In spite of its separate corporate existence the library is still an A.S.M.E. affair. A.S.M.E. members are urged to think of the library, its services, and its needs in this light.

Amelia Earhart

UP to the time of going to press Amelia Earhart, who became an associate of The American Society of Mechanical Engineers in 1931, is still missing somewhere in the Pacific, and hope of finding her daily grows less bright. Miss Earhart staked her life on a supreme test of one of man's most recent and most spectacular engineering devices, and on her resources in flying technique and avigation.

In the few years that have elapsed since the Atlantic crossing successfully completed in 1931, Miss Earhart has done much to popularize aviation, to advance the cause of aeronautical education, and to stimulate interest and opportunities in the professional vocations of women. An enigma to most of the world which sets personal security and physical comfort above all else, she has been true to an inner urge typical of those who must adventure into the unknown, be it in the realms of our physical environment, the human mind, or the wide frontiers of science.

The Educational Dilemma

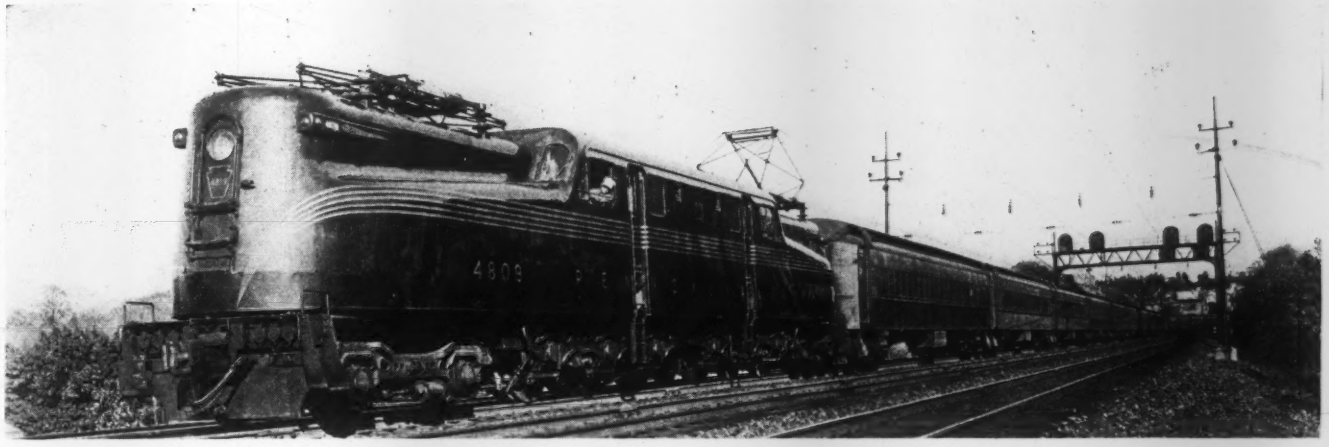
COMMENTING on his matriculation at Harvard in 1854, Henry Adams wrote: "The chief wonder of education is that it does not ruin everybody concerned with it, teachers and taught." So wise and foolish men alike have wondered before and since. And so in different words several speakers at the Cambridge meeting of the S.P.E.E. expressed the same thought.

What a superior education might produce it is hard to say. For, as Henry Adams remarked later concerning Gladstone—"the best educated statesman England ever produced"—the prime minister avowed in his confessions that his speech at Newcastle, in which he said that "Jefferson Davis had made a nation," illustrated "vividly that incapacity which my mind so long retained, and perhaps still exhibits, an incapacity of viewing subjects all round."

Perhaps this "incapacity of viewing subjects all round" is the greatest dilemma education poses. Certainly it has troubled many minds; and in various ways Mr. Orrok brings it up in his S.P.E.E. address published in this issue. So also does Gilbert F. Doan, in an arraignment of engineering education in the summer (1937) issue of *The American Scholar*. He wants "an educated man, not merely a technician," and if Mr. Orrok's formula were followed, an educated man would be the result. Moreover, in spite of the limitations each sees in present methods, educated men are what the best schools are striving to turn out.

Mr. Doan complains that engineering schools go in for a specialization of a vocational type not desired by industrialists who hire the graduates, and that "no S.E.C. board reviews these offerings," by schools, of nonfundamental courses. Perhaps the Engineers' Council for Professional Development may evolve into such a board. Mr. Orrok believes with John Locke that every boy should work at one or two mechanical trades, in business, in manufacture, and acquire "the manual dexterity and experience of earning a livelihood which comes from actual work with workmen." Perhaps this, combined with the other rigors of Mr. Orrok's regimen, would be quite as effective as Mr. Doan's desired background of history and psychology which will enable the engineering graduate "to see the industrial situation in a clearer perspective."

Whether it be Mr. Doan's insistence on formalized liberal education of an apparently academic type, with its danger of postponing entrance to active practice, or Mr. Orrok's integration of fundamentals with hard practical work, which is based on a revision of primary and secondary education, both seek a finer product and both require superior materials and superior teachers. Looking back at what engineers have accomplished with the faulty education they have received, it is indeed a wonder they were not ruined. The future of engineering, which promises to be more complex than its past, demands constant concern with the problem of education, in order to dispose of the dilemma of the "incapacity of viewing subjects all round."



STREAMLINED ELECTRIC LOCOMOTIVE OF THE PENNSYLVANIA RAILROAD NOW IN SERVICE BETWEEN NEW YORK AND WASHINGTON

Modern ELECTRIC UNITS *in* TRANSPORTATION

By H. L. ANDREWS

VICE-PRESIDENT, GENERAL ELECTRIC COMPANY, NEW YORK, N. Y.

THE last ten years have been a remarkable period in the transportation industry. Old methods of providing transportation have given way to more modern ones, and transportation units have kept pace with this rapidly changing condition. Many important and significant developments have been made. Others are now in progress, involving new and unusual types of equipment, for both steam railroads and the urban railway. These new units are fully capable of providing the type and character of transportation demanded to meet present-day requirements of a discriminating riding public.

Electrical equipment contributed to, and in fact paved the way for, the development of these modern transportation units. In many instances, it has made modern high-speed transportation possible, for wherever large quantities of power are required to move a great number of people or large volumes of goods quickly and quietly, no better or more economical means has yet been produced than the use of electric propulsion equipment or electrical equipment as a transmission medium.

Whether the electrical energy is produced in a central station and transmitted to the transportation unit by wire, such as the modern street-car operation in our large cities or electrification of trunk-line railroads, or is generated on the prime mover itself, such as the Diesel-electric locomotive, Diesel-electric high-speed train, and Diesel-electric motorbus, no better, more reliable, or more economical means has yet made itself apparent. Where transportation demands the movement of large numbers of people in congested areas with speed, safety, comfort, and economy, whether this be on the main arteries within our larger cities or on the trunk lines over the mountain ranges on transcontinental railroads, electricity and modern electrical equipment can be considered as superior to all other vehicles.

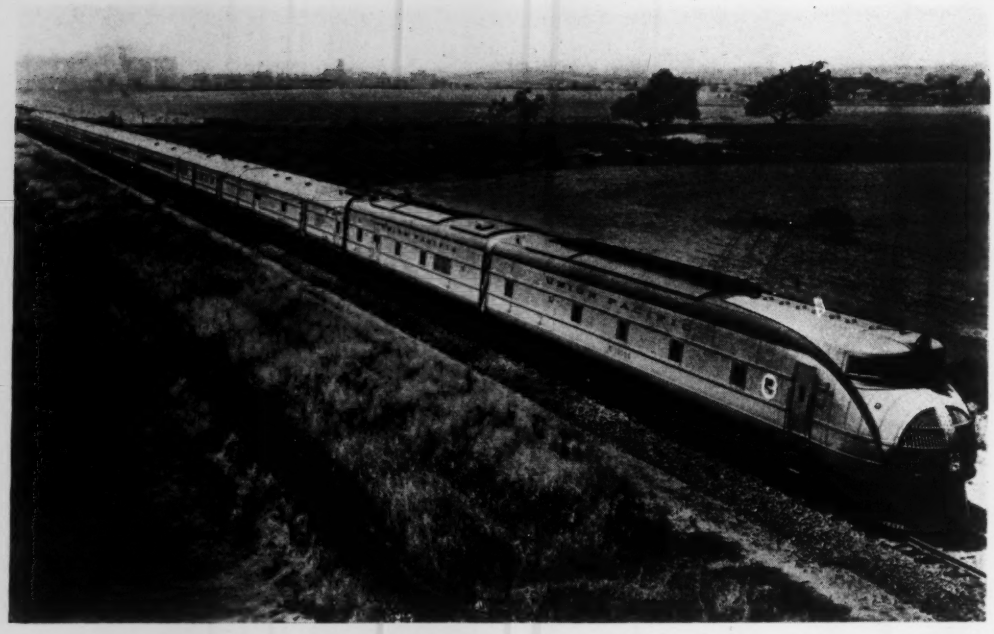
Contributed by the Railroad Division and presented at the Semi-Annual Meeting, Detroit, Mich., May 17–21, 1937, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

TRUNK-LINE AND TERMINAL ELECTRIFICATION

First, let us consider the long-haul or the steam-railroad field—a field where the reciprocating steam locomotive is so generally used and has been so successful in meeting the demands of an exacting transportation system that other types of unit must show some good reason, some great advantage, before being given serious consideration. Expediting train movements, greater availability of motive power, lower maintenance, reduction in cost of fuel, and elimination of smoke and noise are some of the reasons that justify consideration of types of motive power using electricity, either as the principal means of propulsion or in the transmission of power to the wheels of the driving units.

These modern electrical units, which, for some of the foregoing reasons, are making their bid for a place on our trunk-line railroads, are electrification, as represented by the Pennsylvania Railroad trunk-line operation between New York, N. Y., and Washington, D. C., which is now being extended west from Philadelphia to Harrisburg, Pa., and the Diesel-electric locomotive as more popularly typified by the spectacular performance of the high-speed trains of the Union Pacific and Burlington Railroads on the 1000-mile runs from Chicago, Ill., to Denver, Colo., or the long transcontinental runs from Chicago to Pacific Coast points.

The Pennsylvania electrification is probably the most dense transportation system in the world, with trains every hour from New York to Philadelphia and nearly as frequently from New York to Washington, and on the same right of way, are tonnage-freight and perishable-goods trains, the latter running



UNION PACIFIC DIESEL-ELECTRIC STREAMLINED TRAIN *City of Los Angeles*

on passenger-train schedules. It extends through two tunnels and the heart of two of our largest cities and handles 1200-ton trains from New York to Washington, 222 miles in 215 minutes. Locomotives rated at 5000 hp are continuously drawing overloads of 100 per cent when starting and yet do this quietly and quickly. Surely, this is an outstanding illustration of how electric locomotives have challenged and successfully met the supremacy so long held by reciprocating steam locomotives. Many other illustrations of similar challenges and successes for electrification can be found in the tunnel under the Detroit River and the New York Central and New Haven electrifications which, aside from the success of the installations themselves, have made possible the great terminal areas in these cities.

Still other cases may be cited, such as the Chicago, Milwaukee, St. Paul, and Pacific 660-mile electrification stretching over two mountain ranges; or the Great Northern, which, while not quite as extensive, makes the great seven-mile tunnel under the Cascade Mountains a possibility, eliminates severe grades over the mountain range, and shortens the route by many miles; or, again, such terminal electrifications as the Illinois Central at Chicago and the Delaware, Lackawanna & Western at Hoboken, N. J., where 5000 hp is concentrated on a single multiple-unit train to carry passengers quickly and quietly to their suburban homes, relieving terminal congestion and increasing track and terminal capacity. All these are illustrations of the advantages of central-station generated power in economically providing transportation in congested areas and performing a service for the traveling public which is second to none and would not be economically possible with any other type of prime mover.

DIESEL-ELECTRIC LOCOMOTIVES

Another somewhat more recent type of motive power is the Diesel-electric locomotive, where power is generated on the motive-power unit itself and transmitted electrically to the driving wheels of the unit; electrification in a sense, without the use of central-station generated power and a distribution system but with many of the advantages of full electrification. In this case the prime mover, the Diesel engine, is without question the most efficient method developed to date of burning fuel, having a thermal efficiency several times that of the best reciprocating steam locomotive. This great advantage of the Diesel engine, coupled with the advantages of electricity in smoothly and quietly transmitting this efficiently generated power to the driving wheels, provides a unit that is making rapid progress in displacing reciprocating steam power.

So far, its greatest advances have been made in the switching field, where its high fuel economy, high availability, and low maintenance and operating costs enable it to provide transportation at a higher rate and a lower cost than any other motive-power equipment available today. In many installations it reduces the cost of a transportation hour to one half that of other types of motive power. Its principal economy is in fuel and maintenance, although its ease of handling permits it to produce more work in a given time. In many operations, where the work is available, this unit will replace two units of other types, and it operates with an availability of 70 to 80 per cent; that is, many units are operating continuously, 7000 to 7500 hours per year.

From the initial-cost standpoint, it is more expensive than the steam unit it replaces, costing from one and a half to two times the reciprocating type of locomotive, unit for unit. Where operating conditions are such that full use can be made of its inherent advantages, three units will replace two steam locomotives and, in exceptional cases, one unit will replace two steam locomotives. So, where conditions are favorable, the total cost of the Diesel-electric switching locomotive may not exceed the replacement cost of the steam locomotives it displaces, and the reduction in operating cost is a net saving. Seldom does an installation, by savings in operating cost alone, fail to return its original cost in five or, in some cases, four years.

While its greatest use has been in short-movement switching service, its most spectacular service has been in the long main-line runs in high-speed train service. In the space of a few years, it has grown in capacity from 600 hp in a three-car train to 5400 hp handling 14 trailing cars. It is daily making such spectacular runs as those from Chicago to Denver, 1000 miles in 16 hours, or the longer runs from Chicago to Los Angeles, San Francisco, and Portland, 2200 to 2300 miles in less than 40 hours. This operation across the western plains,

The Denver Zephyr, ANOTHER EXAMPLE OF DIESEL-ELECTRIC STREAMLINED TRAIN

traversing great mountain ranges, from altitudes of nearly sea level to those of more than 7000 feet, is truly a spectacular performance to be handled by a single motive-power unit. Aside from the economy of operation, it has served to bring Pacific Coast points nearly one day closer to the Middle West and the Atlantic seaboard and, undoubtedly, has been the principal means of again concentrating the eyes of the traveling public on the railroads and the progress they are making.

As revenue producers, creators of transportation, no question can be raised. The new appointments and passenger conveniences in these modern trains, powered with Diesel-electric locomotives, and the saving in travel time have given a tremendous impetus to rail travel and a material increase in the earning power not only of these modern streamlined Diesel-electric trains; but the renewed interest that they have created in rail passenger transportation has, without question, stimulated travel on the more conventional type of train.

THREE TYPES OF UNIT AVAILABLE FOR LONG HAULS

So at least as evidence of progress in the art of long-haul rail transportation, a greater number of methods are available from which to make a selection; steam locomotives, complete electrification, and Diesel-electric motive power. While a service exists for which each type is most suitable, it is not easy to make a decision unless it is clearly indicated by the conditions. Railroad men are naturally disposed to favor the steam locomotive, and with very good reason. On the other hand, advocates of other methods of conducting transportation sometimes fail to appreciate the railroad man's point of view. The fact must be admitted by every one that the steam locomotive is no longer the only means of moving a train, and we may expect that it will be gradually, and in part, replaced by other types of motive power more suitable for some particular service. This change may take place because of conditions that are unfavorable to steam operation, but in many instances, it will be because of earning a better return on the investment.

Complete electrification will reduce the number of locomotives required, provide a more powerful motive-power unit, decrease the cost of motive-power maintenance, and eliminate the many incidental facilities required by steam power. Against these and many other advantages is an initial investment which is so large that it must be fully justified. It is not always easy to finance a big undertaking, or to convince those who provide the funds. Where the expenditure can be shown conclusively to be warranted, no hesitation about complete electrification should exist.

Unit electrification with Diesel-electric motive power is really a form of electrification with many of its attractive features. It has the advantage of requiring a smaller initial investment and is not limited as to location. Neither does it require any overhead structure and wires. It is not expected to accomplish all that is possible with complete electrification but, nevertheless, has a large field of usefulness. Certainly this type of motive power is challenging the supremacy so long held by reciprocating steam locomotives, and, in making this challenge, it has established for itself a real place in the scheme of supplying transportation and is to be reckoned with as a future contender for an ever increasingly important part in this field.

It is difficult to draw any well-defined field of economic application for each of these types. Every problem is a study in itself. Operating conditions imposed may, in many instances, govern final selection. It is the old problem of balancing increased fixed charges on additional capital involved against economies of operation. Obviously, where operating conditions are such that the motive-power unit may be used in transportation service a large portion of the time, savings in operation will more than overbalance any additional fixed charges that may be involved.

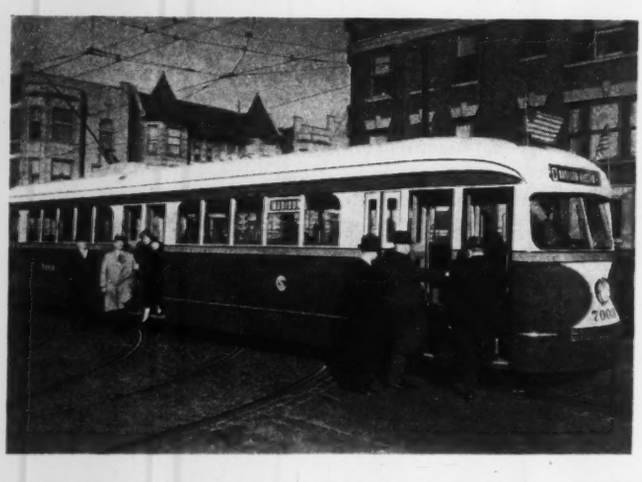
MODERN STREETCARS BEST IN SHORT-HAUL FIELD

Short-haul or urban transportation systems constitute a field where development of the private automobile has materially changed not only the riding habits of the public but also even the public's attitude toward the type of transportation unit used by organized transportation companies. Today, much is heard of the passing of the long-established method of providing this short-haul transportation, the streetcar, and the substitution of other means. Those who speak of this phase as a universal change do so without full knowledge of the facts or of the electrical units which have been developed

115-TON 1000-HP DIESEL-ELECTRIC SWITCHING LOCOMOTIVE

in the last few years and supply modern transportation that is far beyond anything which has so far been produced by other means. Few people realize that, in 1936, $13\frac{1}{4}$ billion riders in the short-haul transportation field used the vehicles of organized transportation companies in 94 of our largest cities which had an aggregate population of 54 millions of people. This means that public transportation was used 250 times during the year by each inhabitant.

Of this total of $13\frac{1}{4}$ billion riders, 76 per cent, or about 10 billion passengers, were carried by the surface railways and subways, and three quarters of these, or $7\frac{1}{2}$ billion passengers, were carried by the surface electric railways of this country. Rapid-transit lines carried about $2\frac{1}{3}$ billion passengers; the remainder was distributed among electrified suburban lines of the steam railroads, trolley busses, and motor busses.



FIRST REAL ADVANCE IN TROLLEY-CAR CONSTRUCTION IN 25 YEARS, PRESIDENTS' CONFERENCE COMMITTEE TROLLEY CAR

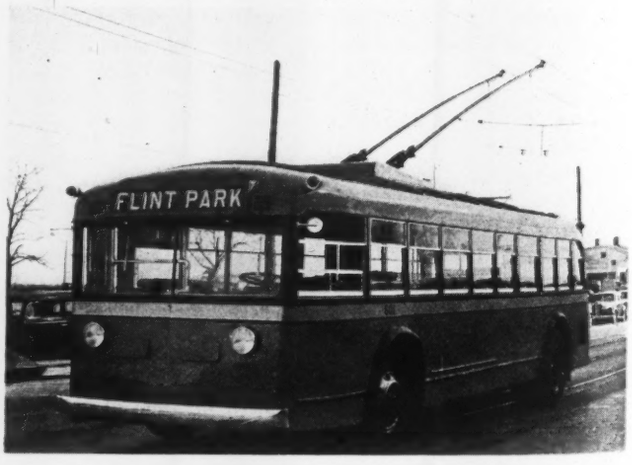
As in the steam-railroad field, where the reciprocating steam locomotive has been so successful in meeting transportation requirements, the electric streetcar has, in the short-haul field, enjoyed a similar position. Before other types of unit are given serious consideration for handling large numbers of passengers on the heavy-density lines in our larger cities, they must show some real advantage, either in expediting the movement of passengers, greater comfort, greater speed, or handling large numbers of passengers in a short time more expeditiously, and at the same time with less congestion on our city streets. So far, no transportation unit, other than those using electricity, has shown its ability to handle the great mass of people better or more expeditiously.

In this short-haul field, the modern electric streetcar, which was developed by the Electric Railway Presidents' Conference Committee and is more popularly known as the P.C.C. car, the electric-trolley bus, and the gas- or Diesel-electric motorbus are the modern transportation units that are making their bids to retain the short-haul transportation field for electrically operated vehicles.

Perhaps the most spectacular of these developments is the P.C.C. car, not only because it embraces the first real advance in trolley-car construction in the last 25 years, but more particularly because it is demonstrating every day in a number of our larger cities, the ability of modern streetcars to supply a form of transportation on heavier traffic lines, which, in every particular, meets the demands of a discriminating traveling public. This car, taking advantage of all developments in the transportation field as well as many of those in the automotive field, with extensive use of rubber in the springing of the car, and new developments in electrical equipment, provides transportation that is more rapid and quieter than one would believe possible on tracks operated in congested city streets. No modern urban-transportation unit has yet been developed which equals the speed, quietness, and passenger-carrying capacity of this modern streetcar. No passenger automobile can accelerate as rapidly, and none can stop more quickly, and all of this is accomplished quietly and smoothly at minimum expense in time and power. As in any field of transportation, this modern car is no panacea for all urban-transportation problems. It will, however, go far toward solving the economical movement of passengers on the heavier traveled lines in our larger cities.

MOTORBUSSES AND RAPID-TRANSIT LINES

On the lighter lines of traffic, its counterpart, the electric-trolley bus, which strangely enough is a development of the automotive, rather than the streetcar, industry, will economically produce the same character of transportation as the modern electric streetcar does on the heavier lines. In reality, the electric-trolley bus is a motorbus operated electrically, thus imparting to the self-propelled motorbus all the advantages of electric operation and high acceleration and breaking rates,



ELECTRIC-TROLLEY BUS SEATING 36 PASSENGERS

combined with quietness of operation and good lighting and heating, while retaining the flexibility of a self-propelled vehicle within the operating limits of a specific route.

Where operation is less frequent or traffic is so light that the investment in the overhead wires that are necessary with the electric-trolley bus is not justified, and self-contained units are desirable from either a flexibility or economic consideration, electricity serves as a means for the transmission of power from the internal-combustion engine, be it gasoline or Diesel, to the driving wheels, providing a smooth flow of power and a more comfortable and speedy ride for the passenger.

In the short-haul or urban field, more units from which to choose are now available. Each has an economic place in the modern scheme of urban transportation. Each, because of the use of electricity either as the means of propulsion or of transmitting power, provides a more rapid, smoother, and quieter ride than any other transportation unit so far developed for this field, and all of this is accomplished with a saving in the total cost of providing transportation per passenger carried and at a considerably lower cost for power.

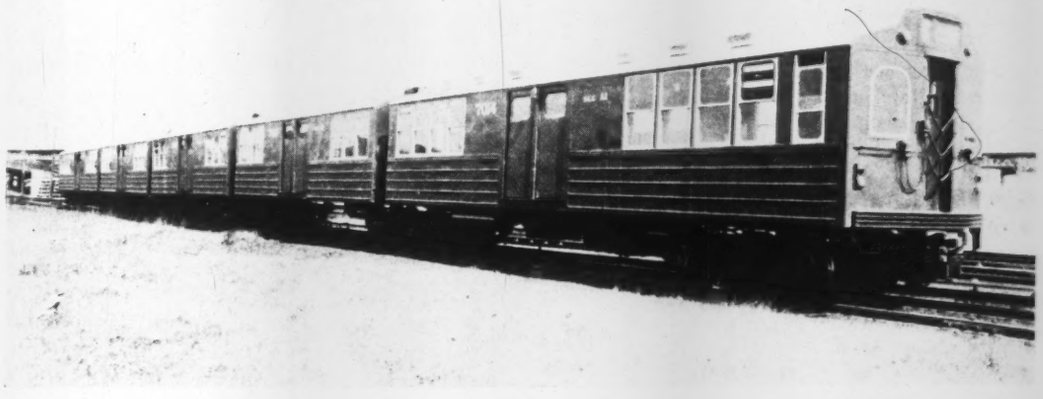
TABLE 1 HOURLY CAPACITIES OF VARIOUS TRANSPORTATION UNITS AND COSTS PER ROUTE MILE

	Passengers per hour	Cost per route mile
30-Passenger motorbusses—15 min headway	180	$ 8,000– 9,000
30-Passenger trackless trolley—15 min headway	180	14,000–15,000
40-Passenger motorbusses—15 min headway	240	12,000
40-Passenger trackless trolley—15 min headway	240	24,000
Fairmount Parkway, Philadelphia	4,000	14,000,000 to 19,000,000
Michigan Avenue, Chicago		
Sixth Ave. Extension, New York		
Wacker Drive—2 levels	5,000	22,000,000
70-Passenger motorbus—40 sec headway	6,300	245,000
70-Passenger trackless trolley—40 sec headway	6,300	275,000
New Jersey State Highway No. 25	9,000	6,000,000
Modern streetcar	10,800	320,000
Modern streetcar—three tracks	16,000	500,000
Interboro subway—older equipment	120,000	.....
New York City Board of Transportation subway—four tracks	180,000	12,000,000

No mention of urban transportation units would be complete without consideration of the rapid-transit lines in our larger cities, operating over private rights of way. While these systems involve large investments of capital, their carrying capacity is enormous. In this, as in other fields of urban transportation, developments have kept pace with changing requirements. The most recent trains for this class of service are known as five-section cars, and consist of five car bodies carried on six trucks with articulated joints at each of the four inside trucks. The electrical and braking equipment, combined with the light weight per passenger, make these cars the most effective carriers of rush-hour traffic in the whole mass-transportation field.

DIESEL-ELECTRIC BUS

In the urban, as in the steam-railroad, field, it is not easy to outline definitely the economic application of each of these electric transportation units, or to draw a fine line of distinction between their economic use in relation to other methods of providing transportation in this field. The prime consideration is the amount of transportation to be provided, the number of passengers to be moved during the rush hours, and the cost of providing this transportation, together with the minimum of street congestion. Perhaps Table 1 will serve to clarify in some respects both the capacities and costs of providing transportation with various electrically operated units as well as other forms that are used in the short-haul field.



FIVE-SECTION ARTICULATED RAPID-TRANSIT CAR

QUALITATIVE ANALYSIS *of* WEAR

Progress Report No. 15 of the A.S.M.E. Special Research Committee on Strength of Gear Teeth

By EARLE BUCKINGHAM

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IN THE last published report of this Special Research Committee[1] (Dynamic Loads on Gear Teeth, 1931), one of the problems noted for future investigation was that of the surface endurance limits of various materials. Since then, a special testing machine has been designed and built, and many tests have been made in the last four years. In addition, careful study has been made of many worn surfaces of gears and other parts in service on many different mechanisms. Here, the attempt has been made to identify, as far as possible, the cause and effect of several distinctive phenomena of wear. In several cases, the conditions believed to be responsible for a certain type of wear were maintained on special setups, and, when the same type of surface failure is obtained under such test conditions, such a qualitative analysis is believed to be substantially correct.

On page 44 of the report "Dynamic Loads on Gear Teeth," three types of wear on gear teeth were noted. Since the time when that report was written, three additional types of wear have been identified. It therefore seems pertinent to start this present series of Progress Reports on Wear with a qualitative analysis of these six types of wear that we have thus far identified.

Thus far, we have noted the following six types of wear, and have identified, with a reasonable degree of accuracy, both their causes and their effects: (*a*) pitting, (*b*) abrasion, (*c*) scoring or cutting, (*d*) spalling, (*e*) galling or scuffing, and (*f*) seizing.

TYPES OF WEAR NOT CAUSED BY LUBRICANT FAILURE

Pitting. As noted in the previous report, pitting appears to be the result of compressive fatigue of the material caused by the repeated high compressive stresses set up by the contact of curved surfaces under load. When these stresses exceed the compressive endurance limit of the material, particles or flakes are sheared out of the surface. The thickness of these flakes, as measured during the tests, varies with the load. For any given material under test, the greater the load, the thicker these flakes become. In general, their thickness checks closely to the distance under the surface of the point of maximum shear stress, for the given load and stress conditions. To avoid this destructive pitting, the loads imposed must be such that the resultant stresses do not exceed the compressive endurance limits of the materials.

Some materials, such as hardened steel for example, do not appear to have any endurance limit. In such cases, continued repetitions of stress, if often enough, eventually result in a fatigue failure. A material must have a certain degree of "crackless plasticity," to borrow a phrase from Dr. Moore of the University of Illinois, to have an endurance limit. With such materials, life can be lengthened by reducing the stresses, but fatigue failure will occur eventually if the stresses are repeated often enough.

As noted also in the previous report, incipient pitting is generally apparent in most cases before destructive pitting occurs and sometimes is present when the stresses are below the endurance limit and no destructive pitting ensues. One suggestion that has been made is that this type of pitting results from the plastic-flow effect on the surface of the material since the tendency is to develop a fiber structure as it is rolled in a fixed direction, and some small particles of material shear out as they are being forced to their new positions in the fiber structure.

With the more plastic materials, when tested under pure-rolling conditions, a definite plastic flow of the surface material occurs. Sometimes this develops into a series of waves on the surface. In such cases, the spacing between the waves tends to increase with continued rolling, and in many cases they eventually disappear entirely. With the introduction of a slight sliding between the two surfaces in generally rolling contact, this corrugation effect is increased greatly and does not tend to disappear again. Under pure-rolling tests on leaded brass, small corrugations appeared; the spacing between them increased; they finally disappeared; then later a pronounced blister extending around nearly three quarters of the circumference of the test roll appeared; and finally this surface lamina began to strip off in very large flakes. This last represented an extreme case of destructive pitting.

Abrasion. Abrasion is caused by the presence of foreign matter such as grit or metallic particles between the contacting surfaces. On gear teeth, it results in scratches or fine grooves running more or less at random in the direction of sliding between the surfaces. Use of a heavier lubricant may reduce the effect of abrasion but will not eliminate it. If the abrasive material is carried between the surfaces by the lubricant, the oil must be properly filtered to avoid this abrasion. If the abrasive consists of particles of material freed by pitting, abrasion may be avoided by sufficiently reducing the loads so that such pitting does not occur. If the abrasive comes from some outside source, such as abrasive particles in the air of a cement mill or free abrasive released from grinding wheels in operation, effective guards should be provided to prevent the abrasive from reaching the contacting surfaces. Information as to the relative resistance of different combinations of materials to abrasion is of value but, as regards this type of wear in the majority of cases, the major problem is to design so as to avoid any likelihood of its occurence.

Scoring. Scoring, or cutting, takes place when, because of other types of wear, rough surface finish, misalignment of parts, or other imperfections, sharp corners or edges are present which cut through the oil film and score the mating surfaces. At

[1] "Dynamic Loads on Gear Teeth," report of the A.S.M.E. Special Research Committee on the Strength of Gear Teeth, published by THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, New York, N. Y., 1931, 71 pp.

times, a scored surface may appear similar to an abraded surface. As a matter of fact, when scoring is present, some abrasion is generally present also, because the particles of material scored out will act as an abrasive. In general, scratches resulting from scoring will have a more regular pattern than those resulting from abrasion. In the majority of cases, scoring is a result of poor workmanship so that the most effective way to avoid it is by exercising more care in producing the mating surfaces.

One type of scoring or cutting on gear teeth takes place when, because of wear, errors in tooth form or spacing, or poorly designed tooth profiles coupled with deformation under load, the entering tip of the tooth of the driven member makes premature contact with the flank of the driving gear. This entering tip travels in a looped path in relation to the driving gear, a path that almost coincides with the profile of the flank of the driving gear, so that a very slight displacement because of error, wear, or deformation under load will permit premature contact to occur.

When this condition exists, the flank of the driving gear will be gouged away and will tend to be shaped to the concave form of the trochoidal path of the tip of the entering tooth, thus resulting in a worn tooth form of double curvature. On worm drives, particularly when the half thread angle is small in relation to the lead angle of the worm, a similar cutting often takes place, so that comparatively large flakes of the bronze of the worm gear are not infrequently found at the bottom of the gear case.

Spalling. Spalling is a type of surface failure that sometimes takes place on the more ductile materials. It occurs when the shear stresses set up by the movement of the elastic and plastic wave ahead of the contact area between the curved surfaces exceed the shear strength of the material. In many respects, it is similar to some types of destructive pitting and results in the shearing out of flakes of material of appreciable size from the surface, but it does not appear to be a phenomenon that is caused by fatigue.

In some cases, spalling occurs when heavily loaded gears are first operated, but, oftentimes, continued operation results in cold-working of the surface and increasing the physical properties of the surface material while reducing the plastic deformation so that spalling ceases and destructive pitting does not develop later. In many cases, a suitable running-in period under increasing loads will cold-work the surface of the material so that this spalling will not take place.

None of the four preceding types of wear is caused by failure of lubrication. Any or all of them may exist under the best possible conditions of lubrication.

FAILURE OF LUBRICANT CAUSES TWO TYPES OF WEAR

Galling. Galling, or scuffing, results from a momentary failure of the oil film, sometimes causing high local temperatures and also a plastic flow of the skin surface of the material. If loose particles of material are released here, some abrasion will also take place. On gear teeth, this galling on more ductile materials results in a ridge at the pitch line of the driven gear and a hollow at the pitch line of the driving gear because sliding is toward the pitch line on the driven gear and away from the pitch line on the driving gear. Too heavy a lubricant on gear teeth often results in such galling because the time between successive contacts of the same pair of teeth is not sufficient for the lubricant to flow back again over the contacting surfaces. In such cases, use of a lighter lubricant will overcome this trouble.

Galling is difficult to prevent between sliding parts which have a slight motion between them or which have a frequently reversing direction of relative sliding because, under such conditions, a continuous oil film cannot be formed and maintained. At the other extreme, galling often takes place when the loads are heavy and the rate of sliding is high, because of the frictional heat and the necessity of using relatively light oils under such conditions. In such cases, the oil film is not strong enough to support the load, and, as a consequence, momentary metallic contact between the sliding surfaces is of frequent occurence.

Seizing. Seizing, in many respects, is an extreme case of galling. In this case, local temperatures are so high during the momentary failures of the oil film that particles of material are actually welded or brazed onto the contacting surfaces. On gear teeth, such particles so welded on the tooth surfaces then act to score the mating tooth surfaces. In the case of plain cylindrical bearings, such particles of material may actually weld the two members together. To minimize or overcome both galling and seizing, many special lubricants, commonly known as E.P. (extreme pressure) lubricants, have been developed. Where sulphur or chlorine is added to the lubricant for this purpose, the probabilities are that these elements act as an antiflux and thus prevent the particles from welding onto the contacting surfaces. Of the six foregoing types of wear, failure of lubrication is responsible for only the last two, galling and seizing.

GEAR-TEETH CONTACTS WEAR AWAY SMALL PARTICLES OF METAL

The statement is made in one of the British standard specifications for gears to the effect that every time a pair of gear teeth makes contact, small particles of material are worn away, thus resulting in a slow but relatively uniform wearing away of the surfaces. Such a condition exists only in the case of abrasion, provided that the quantity and quality of the abrasive is constant; or, in the case of scoring, provided that the cutting edges are not worn down and dulled. In most cases, the wear on gear teeth is of a periodic nature. For example, if the tooth surfaces are rough, wear will be rapid at the start because of the scoring and resulting abrasion. After the rough surfaces or sharp edges have been worn down and the abrasive particles of material have worked free of the contacting surfaces, practically no further wear is evident for a greater or lesser time, depending upon the intensity of the load. Under heavy load, the next cycle of wear will start when more particles of material are released because of the surface fatigue of the material. Then further abrasion takes place, oftentimes followed by scoring or cutting caused by the entering tip of the tooth of the driven gear gouging out the flank of the driving gear. After this tip has cleared its path and the released abrasive particles of the material have worked free of the contacting surfaces, another period free from wear ensues until the same cycle is repeated again. Under suitable conditions of load and lubrication, gear teeth may run indefinitely without any signs of appreciable wear.

In addition to the foregoing, the problem of wear is complicated by the interaction of different materials on each other. We learn from experience that certain combinations of materials work well together, while others do not. Furthermore, with a given construction, a combination of materials that works well in given respective positions may not be satisfactory when the materials used for the mating parts are reversed. For example, cast iron and bronze appeared to be a good working combination. A cast-iron worm mating with a bronze worm gear shows high resistance to wear, but a bronze worm mating with a cast-iron worm wheel shows relatively poor resistance. In this case, our experience with these and other combinations of materials teaches us that the enveloping member or worm gear

should always be made of the more plastic material of the combination used.

Other conditions constantly occur where a plausible explanation of cause and effect is not so evident. Thus for example, why does bronze operate well, as regards resistance to wear, with cast iron and hardened steel, but not with soft steel, bronze, or phenolic laminated materials? Also, why does soft steel operate well with cast iron, babbitt, soft brasses, and sometimes with hardened steel, but not with bronze, soft steel, or laminated phenolic materials? Why does hardened steel operate well with soft bronzes, brass, cast iron, babbitt, phenolic laminated materials, and often with hardened steel, but not with the harder heat-treated alloy bronzes? Oil-hardened steel does not always operate well with case-hardened steel Again, two hardened nickel steels do not operate well together always, particularly when any appreciable heat exists. Also difficulties exist when a hardened nickel-steel worm is mated with a nickel-bronze worm gear. Why does cast iron generally operate well with all other materials? Yet cast iron, in the "as cast" condition, is not nearly as satisfactory as when it is suitably heat-treated.

The major purpose of a qualitative analysis is that of a signpost, pointing the way to the most promising fields for more detailed investigation. For many reasons, the detailed study and quantitative analysis of pitting and surface fatigue of materials, and the establishment of the surface endurance limits of the more commonly used materials appear to the author among the most important and useful steps to be taken first.

IMPORTANCE AND USES OF ENDURANCE LIMITS OF MATERIALS

Logically, the working stresses used for the design of many machine parts should be based upon the endurance limits of the materials rather than upon their ultimate strength, elastic limit, or yield point. The endurance limit is that stress which can be repeated indefinitely without causing fatigue failure. To insure long life to any mechanism, the stresses imposed in actual service should be kept within the endurance limits of the materials employed in the construction of the mechanism. In many respects, many materials appear to have much in common with human muscles; when they are stressed within their endurance limits, their strength increases with repeated stressing, or exercise; when they are stressed beyond their endurance limit with repeated stressing they will be permanently weakened, and, eventually, they will fail by fatigue.

As noted before, all materials do not appear to have a definite endurance limit. To have an endurance limit, a material must have some degree of crackless plasticity, or the ability to arrange its structure, without developing cracks, to meet and resist the specific stresses set up by the loads imposed. Thus for example, steel hardened above spring temper does not appear to have any endurance limit. Its life may be lengthened by reducing the load, but, eventually, fatigue failure occurs when the stresses are repeated often enough. As regards the surface failure between curved surfaces of hardened steel, tests seem to indicate that

$$C = NL(10/3)$$

where

C = experimental constant
L = applied load
N = number of repetitions of load

Thus, if the load is doubled, the life will be about one tenth of the original life; if the load is reduced to one half of the original load, then the life will be about ten times the original life. If the endurance limits, both flexional and surface, of materials are known and are used as the basis for the working stresses, then the designer can design a given mechanism that will stand up against both breakage and excessive wear. Or again, if a limited life is acceptable, the designer can proceed with his work accordingly and with much more assurance than is now possible.

However, at present in the great majority of cases, the designer is ignorant of one of the most important factors of machine design. This is the knowledge of the actual intensity of the dynamic or maximum momentary loads which exist at various parts of the mechanism under the service conditions. Today, this part of machine design is empirical almost without any exception.

Designs have been developed by trial and experiment until they perform well in certain limited fields. If that mechanism, however successful it may be in its usual application, is used under more severe conditions than before, oftentimes, it proves to be inadequate for such new use. For example, designers of commercial motor trucks have developed, from years of actual experience and experiment, designs that prove adequate for commercial hauling, most of which is done on hard roads. If these same vehicles, however, are used to bring supplies to an army in the field, over wrecked roads or no roads at all, the chances are that the average service conditions here would impose average loads of more than double those of commercial hauling. Under these conditions, with the many hardened-steel parts involved in the construction of the trucks, the useful life of such vehicles would probably be less than one tenth of their life when used commercially. The motor-transport breakdown in Ethiopia was to be expected, when commercial trucks were used, by anyone who had an appreciation of fatigue phenomena.

In the same way, considerable uncertainty exists as to the real load capacity of many other units. Take, for another example, geared speed reducers. Here may be one that has run successfully for several years, transmitting the power from, say, a 10-hp motor to a given machine. This does not mean, however, that the average transmitted power has been 10 hp. It may have been nearer 2 or 3 hp. Yet the inclination is to rate such a speed reducer at the same power as the rating of the motor to which it has been attached.

The designer may know the extent of the useful or applied loads on the several parts of a given mechanism, but the actual intensity of the dynamic load is generally a profound mystery. In the experimental stages, a part may break. This gives some measure of the stresses existing in that part, but such breakage often causes other damage to the mechanism, including breakage of other parts. Under such conditions, to determine which part broke first is difficult or impossible.

If the surface-fatigue characteristics of the materials used are known and the surfaces are carefully watched, dynamic loads that caused surface failure can be detected before any harm is done to any other part of the mechanism, and a reasonably close measure of their intensity can be made from the condition and appearance of the surface failure of the specific part. In other words, the surface of the material itself, on which is imposed the dynamic loads, can be used as an indicator or measure of the extent of these loads. In cases where no surface failure is evident and knowledge of the intensity of the dynamic load is desired, a part of weaker surface strength may be substituted for the original one until the desired information is obtained. Thus, a greater knowledge of the surface-fatigue characteristics of materials will prove to be a most valuable tool for the study of the dynamics of many types of mechanism and a measure of the actual intensity of the dynamic loads existing there, a subject of which, today, our knowledge is practically zero.

The Technique of WEATHER FORECASTING

By IRVING KRICK

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UNTIL A few years ago, weather prediction could be called a pseudo science, since purely empirical or statistical considerations formed the basis for its development. However, in the last decade, sufficient progress has been made, both in the quantitative treatment of atmospheric phenomena and in the less exact processes of weather forecasting, to place meteorology upon a firmer foundation and bring it a step closer to the more dignified position of a science.

Foretelling the weather may never become an exact science due to the infinite amount of material necessary to determine the boundary conditions in the atmosphere which are required for integrating the hydrodynamic and thermodynamic equations involved in an exact solution. Even though sufficient data were available, the processes of integration would require so much time that the weather would be over before it could be forecast. Therefore, the synoptic meteorologist is obliged to resort to approximate methods, usually graphical ones, in determining weather changes. In recent years, purely empirical methods of prediction have been discarded and charts and graphs developed which have a physical meaning and provide for the prediction of short-range weather changes with sufficient accuracy for all practical purposes.

In the past, weather prediction was based entirely upon surface observations and the application of empirical rules developed from the observation of migrating pressure centers known as "highs" and "lows." These methods provided the basis for all forecasting services and, indeed, still do in a number of countries, although, in most cases, steps are being taken to adopt some of the newer concepts. Utilizing such a method, an accuracy of only about 70 per cent is possible for predictions of 24 to 36 hours. Furthermore, the forecaster is not in a position to check errors, since no physical basis for the forecasts exists, and errors of the same nature are often repeated. Thus, the forecasting technique that has been in vogue for almost a century was doomed to stagnation from the beginning.

OVER 90 PER CENT OF WEATHER FORECASTS ARE NOW ACCURATE

In the last four years more advances have been made in meteorology than in the preceding century, largely due to the requirements of commercial and military aviation and to an attempt to explain atmospheric phenomena from a physical point of view. This has resulted in an accuracy of well over 90 per cent for 24- to 36-hour forecasts in areas where sufficient data are available. We owe this new stimulus to a Norwegian family by the name of Bjerknes, who not only conceived a rational theory of the structure of weather disturbances in the middle latitudes but also developed it to the point of practical application.

Let us briefly review the fundamental concepts of the Norwegian school of meteorology and the elements that have been developed in the United States in the last few years. Extensive portions of the earth's atmosphere have been found to approximate horizontal homogeneity. Such a body of air has been termed an "air mass" and may cover more than a million square miles and extend to a height of six or seven miles. Formation of an air mass usually results from stagnation of a vast portion of the earth's atmosphere over some rather uniform surface, either continental or maritime in nature, for a period sufficiently long to enable its properties to reach equilibrium with respect to the surface beneath. The area where an air mass attains its initial characteristics may be termed its "source region."

Sooner or later, air masses formed in this manner take part in the general circulation of the atmosphere and leave their source regions, which are areas usually confined either to high or low latitudes. This movement carries the air across the middle latitudes where a modification in its initial structure may take place, particularly in the lower layers, due to the changes in the thermal properties of the surface over which it is passing. However, these changes do not ordinarily cause abrupt transitions within the air masses, and, therefore, they may be still classified as entities having definite physical characteristics. Obviously, air masses originating in cold polar regions differ in structure from those obtaining their original characteristics over warm tropical latitudes.

In the course of their migration over the earth's surface, dissimilar air-mass types frequently approach one another. In such cases, instead of simply mixing, a rather definite boundary or surface of discontinuity arises between them. This is called a "front" and plays a major rôle in modern weather analysis. Formation of such discontinuities in the atmosphere is readily understood if we realize that the two dissimilar air masses may be treated as different fluids, since the cold, dry, polar masses will be heavier than the warm, moist, tropical ones. For this reason, cold masses tend to underlie the warmer types.

A simple illustration of a discontinuity-surface formation between two dissimilar fluids is afforded when oil and water are confined in a vessel. If the fluids are allowed to reach the equilibrium state, the water underlies the oil, since it is the heavier. A definite boundary surface becomes visible between them and, if the fluids are not in motion, will assume a horizontal position. This is entirely analogous to an atmospheric boundary surface separating polar and equatorial air currents. However, in the atmosphere, the fluids involved are ordinarily in motion, a condition that brings forces into play which cause the discontinuity surface to become a sloping one. It assumes a position such that the cold heavy air of the system underlies the warm lighter type in the form of a very flat wedge. The average slope of a discontinuity surface in the lower levels of the atmosphere is of the order of 1 to 100.

ATMOSPHERIC DISCONTINUITY SURFACES SELDOM REMAIN STABLE

Once an atmospheric discontinuity surface is formed, it seldom retains its equilibrium position. Therefore, we must investigate the development that will take place as accelerations arise along the front. Here, again, we may turn to a more

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familiar hydrodynamic analogy; the disturbance of a water surface which is a discontinuity between a body of water and the air above it. Any disturbance of this surface, as determined by observation or from a rigid mathematical treatment, results in the formation of a wave along it. For example, a gentle breeze blowing across a water surface produces waves of a certain period, length, and amplitude on the water. A higher wind velocity will induce waves of greater amplitude, a longer period, and a longer wave length to form on the surface of the water, and, finally, if the wind velocity exceeds a certain limiting value, the tops of the waves are removed in the form of whitecaps, indicating that the discontinuity surface between the air and water has become dynamically unstable and that the two fluids are tend ing to whirl together. In the atmosphere, a similar development takes place when the boundary between two different air masses is disturbed by an acceleration of either air mass adjacent to it. In this case, the waves that are formed have characteristics different from those produced on a water surface but obey the same physical laws. Thus, a forecaster with an understanding of wave theory is in a position to determine, at least qualitatively, the properties of the phenomena, such as wave length, period, amplitude, and direction and rate of their propagation.

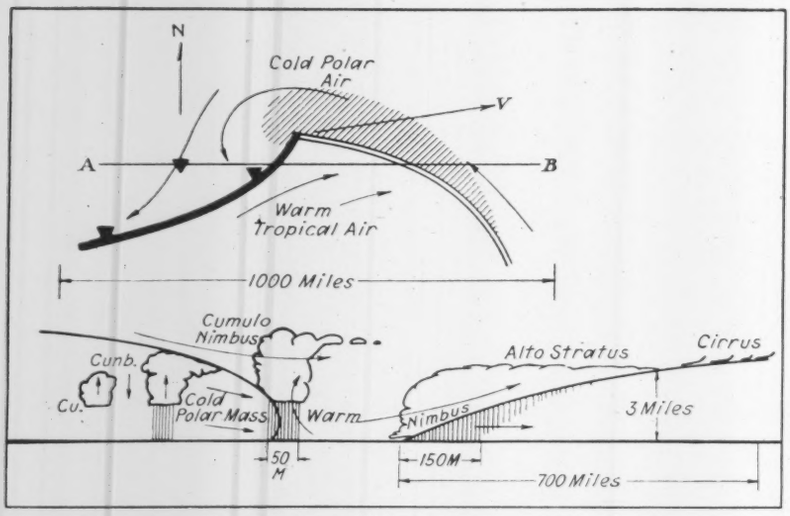

FIG. 1 IDEALIZED CYCLONE OF THE MIDDLE LATITUDES

Atmospheric waves are easily spotted on the weather chart because the sloping discontinuity surface along which they form must intersect the ground. Its trace along the earth's surface can be plotted accurately from synoptic surface observations. When these atmospheric waves become unstable, a condition arises analogous to the formation of whitecaps on the ocean or breakers on the beach. The two air masses tend to whirl together, transforming the phenomenon occurring along the discontinuity from a wave to a vortex. As long as the wave along the discontinuity surface is a stable one, the air masses adjacent to the front take no part in the movement of the wave other than to oscillate during its passage. However, if the wave becomes unstable, as is normally the case, the air masses take part in the circulation, and their movement becomes important to the forecaster. Air-mass movements on the weather chart can be determined readily, and appropriate symbols for the designation of the types encountered entered on the chart. These may be altered slightly from day to day in such a way that the forecaster is continually informed as to the source and history of the air masses traversing his charts. On a weather map, the crest of a newly formed wave along an atmospheric discontinuity, consisting usually of a northward-moving tropical air mass, occupies the center of lowest atmospheric pressure. The major precipitation areas occur along the atmospheric fronts radiating from its center. On the forward side of the "low," precipitation often occurs from a lifting of the warm, moist, tropical air of the system over the wedge of cold air in its path as it moves northward. Furthermore, to the rear of the system, the warm air is pushed aloft by an active outflow of polar air moving southward, thus producing a narrow showery precipitation belt. Associated cloud types, as well as the nature of the resulting precipitation, are a function of both the thermal structure of the rising air masses and the field of motion within the system. Therefore, very definite knowledge of the vertical distribution of temperature and moisture in all air masses encountered on the weather chart is essential to the forecaster in determining interactions between various air masses at their boundary surfaces and changes in the structure of the individual air masses brought about by the action of the field of motion upon them.

MIDDLE-LATITUDE CYCLONES

Fig. 1 represents an idealized wave along an atmospheric discontinuity surface, in both horizontal and vertical projections. This is synonymous with the well-known low-pressure area or cyclone of the middle latitudes. The upper drawing is the horizontal projection or map of the system and shows a warm tongue of tropical air projecting northward surrounded by a cold polar mass. The shaded area on the forward side of the system represents a region where steady rain is falling.

This is caused by the tropical current overrunning the polar mass. Flow in the two types of air is indicated by arrows. It changes abruptly as we cross the fronts, indicating that, on the forward side of the disturbance, warm tropical air is forced to climb a wedge of cold polar air, and, to the rear of the system, a wedge of cold air is forcing its way into the warm tropical current. The arrow V indicates the direction in which the system is moving. A vertical cross section along the line A-B is shown in the lower portion of the illustration. On the forward side of the cyclone, the wedge of cold air is being overrun by the warm tropical current with the consequent production of clouds and precipitation, caused by cooling of the warm air in its ascent. This cooling results largely from expansion of the air as it moves aloft to regions of lower pressure. To the rear of the cyclone, a cold mass of air is pushing into the warm current, lifting it along its forward edge, and also producing clouds and precipitation. In this case, the slope of the front near the ground is much steeper than that on the forward side of the cyclone. This is due to the frictional drag between the lower air layers and the ground, which tends to steepen the front to the rear of the cyclone and decrease its slope on the forward side. A few important dimensions of the system have been included to help the reader visualize the magnitude of the various elements.

From this discussion, the old rule associating bad weather with a low-pressure area is seen still to hold true in the majority of cases. However, the entire low-pressure area is not affected by the precipitation, but merely those regions where

vertical motion occurs. Furthermore, if the warm air is not moist, no amount of lifting over the colder current or an intrusion of cold air will produce precipitation. Thus, all low-pressure areas are not necessarily accompanied by precipitation, the rain being largely a function of the structure of the warm air of the system.

One of the principal problems of the weather forecaster is to plot accurately upon his chart the boundaries between various types of air from the available observational material. To determine the variation of temperature and humidity with elevation, airplane flights to heights of about three miles are made daily at many stations throughout the country. Use of these soundings enables the forecaster to determine not only the physical structure of the various types of air plotted upon his chart but also the positions of atmospheric boundaries aloft, so that the slope of important discontinuities can be determined readily. This slope, coupled with a knowledge of winds aloft, which indicate air-mass movements, enables the forecaster to determine how fast air is being lifted over a frontal surface and, therefore, its rate of cooling and approximately when and where precipitation will develop. When the weather becomes unflyable, these important data are lost, and errors in prediction may arise. At present, efforts are being made at various institutions throughout the world to overcome this difficulty. One solution of the problem will be to send small balloons aloft, which are equipped with instruments capable of providing the same information as is now obtained from airplane flights and a small radio transmitter that will send the data to the ground where they will be automatically recorded. Operation of this instrument will be independent of weather conditions. Furthermore, it will rise to much higher levels than the present airplanes and relay the information to the ground even more rapidly. It will open up the field of upper-air exploration over the oceans, as yet practically untouched but extremely important in all meteorological considerations. Recent flights with instruments of this type which are being constructed at the California Institute of Technology have attained average altitudes of over 50,000 feet while continuously transmitting to the earth the various meteorological elements desired. Although, normally, the equipment is lost following each flight, the manufacturing cost can be made less than that of the present airplane flights, thus making the immediate use of such a device practicable.

CHARTING AIR-MASS MOVEMENTS

Once the map is prepared, the weather at a particular station becomes a function of the characteristics of the air masses present in the forecast interval and the phenomena accompanying the passage of fronts in this period. Fig. 2 illustrates a completed weather chart for the western part of the United States and for the Pacific Ocean. This map is drawn from synoptic weather observations from the continent and the adjacent oceans, taken at 5 a.m. Pacific standard time, April 17, 1935. Location of the fronts is determined from both surface and upper-air information. Heavy solid lines represent a front where cold air is displacing warm, double lines are used for fronts where warm air is overrunning the colder, and heavy broken lines indicate where cold air behind a disturbance has overtaken the forward front of the system, closing up the warm tongue of tropical air initially extending to the center of the system. After the location of the fronts, lines of equal pressure are drawn on the chart for every 0.1 in., much as the contours on a topographical map.

In this case, the valleys will be low-pressure areas and the knolls high-pressure areas. Low-pressure centers are marked with the letter *L* and high-pressure centers with the letter *H*. All waves along atmospheric fronts in their initial stages are seen to be centered in low-pressure areas, and, even the older systems, shown by the heavy broken lines, have their fronts terminating at the center of lowest pressure.

Symbols for the various air masses indicating the type and the history of the air since it left its source region are plotted at appropriate points. Elementary symbols are as follows: P_C denoting polar air of continental origin, P_P polar air originating over the North Pacific Ocean, T_G tropical maritime air from the Gulf of Mexico, and T_P tropical air from the warmer portions of the North Pacific Ocean. Subscripts to the left of the symbol indicate the number of days the air has passed over a water surface, while those to the right represent the number of days it has passed over a land surface since leaving its source region. Thus, the air over eastern Utah, ${}_3P_{P1}$, has moved for three days over the waters of the North Pacific and for one day over the land after reaching Washington and Oregon. This air is sepa-

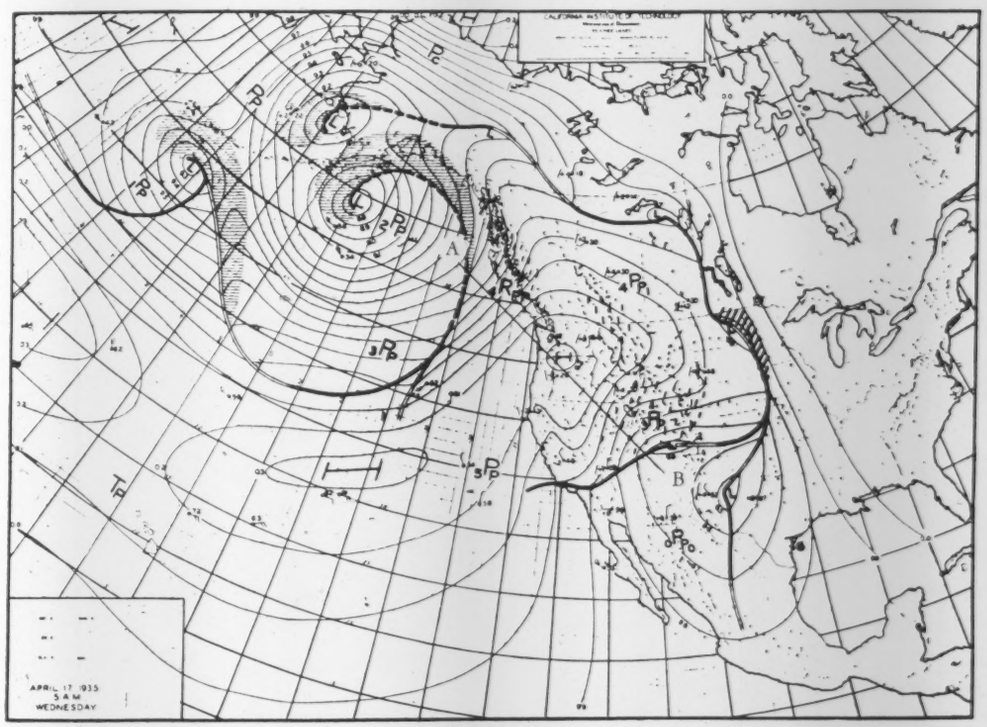

FIG. 2 COMPLETED WEATHER CHART FOR THE WESTERN UNITED STATES AND THE ADJACENT PACIFIC OCEAN

rated from the air to its south, ${}_0P_{P0}$, by the discontinuity surface shown on the map. The latter air mass has had a long sojourn both over land and water surfaces and is, therefore, considered to be an old polar mass with respect to both surfaces. Out over the North Pacific we see a heavy broken line indicating a front between rather fresh polar Pacific air, ${}_3P_P$, and an older type returning to its source denoted by the symbol ${}_4R_{PP}$. From this surface map, the forecaster must visualize the vertical structure of the atmosphere. An idealized vertical cross section along the line *A-B* on the map is illustrated in Fig. 3. The vertical scale has been greatly exaggerated to bring out the slopes of the various discontinuity surfaces. Over the Pacific Ocean may be noted the boundary between the fresh polar Pacific air and the older returning type with tropical air overlying the two cold masses. Farther east over the Great Basin, may be noted the upper limit of the cold polar air with the tropical Pacific air lying at higher levels. The cold air in this case only extends to an altitude of about 4 miles, or 6 km, the unit used on the illustration. Above these air masses, another wavy line is shown which separates the lower levels of the atmosphere known as the "troposphere" from the higher levels of a somewhat different structure known as the "stratosphere." The forecaster must study the oscillations of this boundary as well as those between the air masses in the lower levels of the atmosphere, if accurate forecasts are to be made for periods of five days or more.

WEATHER MAPS THE BASIS FOR FORECASTING

After the weather map has been completed, the forecaster must compute the movements of the various fronts on the chart, as well as the developments that will take place along them in the forecast period. In addition, any changes in the structure of the air masses adjacent to the fronts, either by movement over the earth's surface or by internal motions, must be estimated or calculated when possible and desirable. By so doing, the phenomena occurring within an air mass which will affect a given station in the forecast period are determined, together with any disturbances resulting from a frontal passage during the forecast period. Both the identification of air masses and the determination of their phenomena, such as showers, characteristic cloud types, fogs, and the like, can be determined accurately from specially constructed thermodynamic diagrams which provide for rapid calculation of the factors involved. Projection of the frontal systems in the forecast period, together with the developments along them, are determined by application of hydrodynamic equations to the field of pressure drawn on the charts.

The scope of this paper will not permit a detailed discussion of the methods used in determining air-mass structures and the developments of disturbances along the fronts. It will suffice to point out that, through use of these methods, weather prediction in the last few years has become accurate enough to warrant more extensive commercial application. This was first recognized by commercial and military aviation services, inasmuch as their weather problems are three-dimensional and are best attacked through use of the principles previously outlined.

Since the method provides for overcoming the difficulties involved in preparing the detailed forecasts essential to air-line operation, it will also meet most of the requirements in other fields. Successful application to motion-picture production, growing and marketing of citrus products, department-store advertising campaigns, and dam and highway construction projects, has been made by the author, thus demonstrating the practical aspects of the development. It is hoped that continued research will lead to the possibility of preparing seasonal forecasts of commercial value. The problem offers many complexities, but unraveling the interdependence of the various parameters involved should be possible eventually through a continued study of the physical aspects of weather phenomena. Needless to say, finding a satisfactory solution of the longer-range forecasting problem will result in even greater benefits than have already been secured in the case of the shorter-period fluctuations.

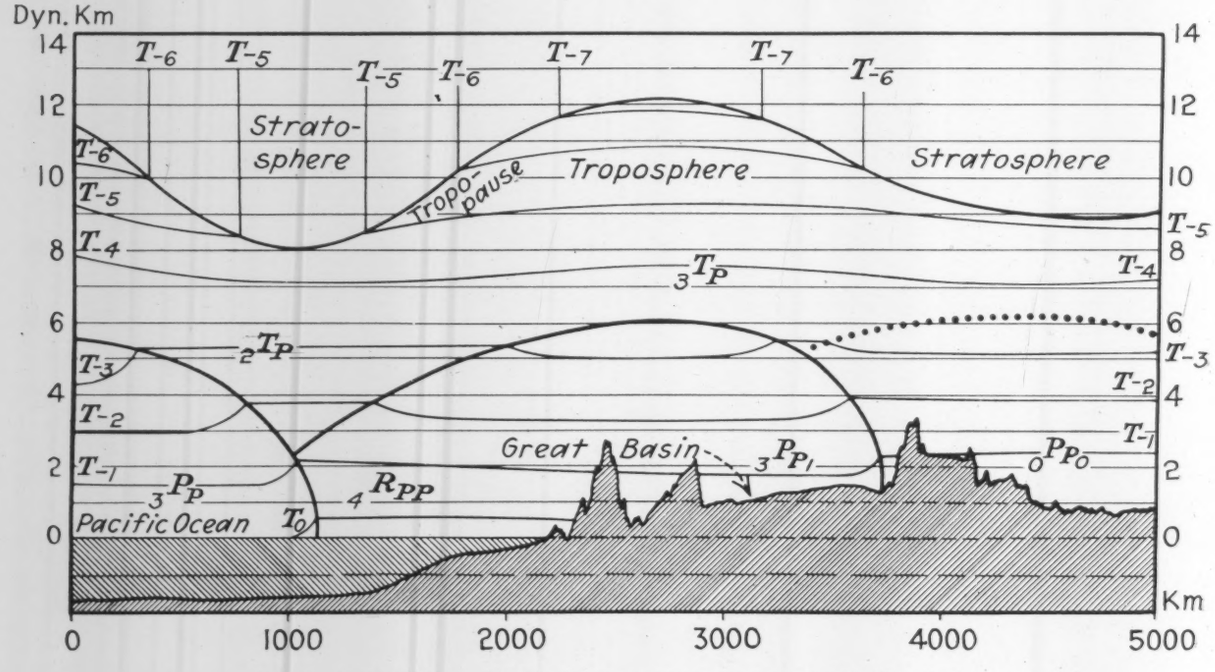

FIG. 3 IDEALIZED VERTICAL CROSS SECTION ALONG THE LINE *A–B*, FIG. 2

The OIL INDUSTRY *in* MICHIGAN

By C. R. MILLER

SOCONY-VACUUM OIL COMPANY, DETROIT, MICH.

What is the future of the petroleum industry in Michigan? Some predict that Michigan will be the greatest oil-producing state in the union. I am inclined to think that this is a case where "The wish is father to the thought." On the other hand, more conservative individuals feel that Michigan does not have the possibility of becoming an exceptionally great oil-producing state. They believe that occasional pockets of oil, such as those described and which are capable of producing perhaps as much as eight or ten million barrels while they are in production will be discovered. They feel that these pockets may be more or less numerous but will be difficult to locate and that on the whole Michigan will continue to produce and new fields will be discovered now and then. These will keep the state on the map as an oil-producing factor in this great industry.

IN THINKING of Michigan's natural resources, such items as salt, iron, copper, lumber, fish, and coal usually come to mind. Few would give oil a position of importance among the state's resources; yet, in the last decade, Michigan reached a position of importance in this particular field.

In any search for petroleum, certain geological conditions are essential if considerable deposits are to be found. Petroleum is usually found deposited in what are known as oil sands trapped beneath solid rock which prevents its migration or ultimate escape. Usually, surface indications of oil-bearing material are also found in the fossilized remains of sea-animal life from which the oil was originally formed. These fossils are generally found in the outcroppings of rock, and the oil deposits may be found at some point farther beneath the surface.

GREAT BASIN OF ROCK LIES UNDERNEATH MICHIGAN

In the early days of the industry, Michigan was not considered as having promising geological structures from which it could be expected that oil would be produced. Geologists describe its underground rock formation as being that of a great basin sloping downward toward the center of the state from the outer boundaries. The principal rock formations are found near the surface along Lake Huron near Alpena, sloping to a depth of approximately 2500 ft in the center of the state, around Mount Pleasant, and then coming to the surface again in the southwestern part of the state near Dowagiac and South Bend, Ind.

Lying far below the main formations from which much Michigan oil has been produced is a formation known as the Trenton Black River. This also outcrops on the northeastern corner of Michigan and comes near the surface at the Indiana line, but in the center of the state it dips far beneath the 6000-ft level. As a matter of fact, the bottom of the dip has never been reached by the drill. This brief description indicates the reason for Michigan's being referred to as a great basin.

The principal rock formation, from which the greatest quantity of oil has been produced in the central Michigan area, is the Dundee. Another productive formation is the Traverse, but the latter has not been as productive as the former. The fact that Michigan is part of a great basin and little surface evidence of oil was apparent led early geologists to believe that Michigan would never amount to much as an oil-producing state. They thought that a few, occasional pockets might be found which would be productive, but that sufficient oil would not be available to make it a commercial proposition. In the early days, slight indications of oil were found in some of the salt wells drilled along the eastern side of the state and small deposits of crude were found around Port Huron and Saginaw.

The structure in which oil is found in the Michigan fields differs considerably from that in most of the other large producing areas. Ordinarily, crude petroleum is trapped in a sandy structure underlying a hard-rock stratum. The oil saturates the sand, filling in the spaces between the particles. When the oil sand is penetrated by the drill, the rock pressure under which the oil exists causes it to migrate through the opening and to rush to the surface with considerable velocity.

As a rule, all that is necessary to break loose the sandy structure and allow the oil to flow without any great restriction is to discharge a quantity of nitroglycerin in the oil-producing sand. This usually results in shattering the structure so that the oil flows readily, and the production of the well is thus greatly augmented.

In the Michigan fields, the situation is somewhat different because, instead of being trapped in a sandy structure, the oil is found in a more or less porous rock structure. This condition greatly retards the flow of oil, and means must be found to open the pores and allow the oil to come to the drill hole. Nitroglycerin has not proved to be entirely satisfactory for this purpose, and after considerable study and research, the introduction of acid into the rock structure was found to accomplish what the explosive did in the sand structure of the other fields. Acid, naturally, has a chemical action on the rock, dissolving it to a certain extent, penetrating in all directions through the porous structure, and thus opening channels through which the crude petroleum can flow freely.

MICHIGAN FIRST PRODUCED OIL COMMERCIALLY IN 1925

The first real commercial production of oil in Michigan took place in what is known as the Saginaw field in 1925, the total production being approximately 4000 bbl. This increased to 94,000 bbl in 1926, and 434,000 bbl in 1927, and then declined in 1928 to 231,000 bbl. Production was 113,000 bbl in 1929, and the decline in this field continued until, in 1936, only 27,000 bbl were produced. The total quantity of crude produced in the Saginaw field from 1925 to 1936 was 1,248,523 bbl. Due to the small current production in this field, the Saginaw is not considered of any great importance at present.

With the development of the Muskegon field, the oil industry first began to attract attention in Michigan. Due to favorable conditions, efforts were made as far back as 1872 to 1875 to find salt in and around Muskegon, and, in drilling for this material, an occasional showing of oil was encountered. The discovery well in this field which led to its development as a producing

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area was drilled on Dec. 8, 1927, by the Dixie Oil Company, and the location was chosen by its geologist, Hugh B. Crider. It was drilled to what is known as the Traverse formation at a depth of 1360 ft and produced approximately one half million cubic feet of gas daily. A little later this well was deepened, and an initial daily production of 350 bbl of oil was the result. Naturally, the field developed rather rapidly, and soon a number of large producing oil and gas wells were in operation. In August, 1929, the field reached its peak of production with approximately 18,500 bbl per day. Of course, 1929 was the peak year for this territory, a total of 3,157,668 bbl having been produced. From then, the field declined rapidly and in 1936 only 96,629 bbl were produced. From the drilling of the first well to Jan. 1, 1937, approximately 6,400,000 bbl of oil were brought to the surface. Of course, in this time, considerable gas was produced and for a period of several years supplied a number of the larger industries around Muskegon with inexpensive fuel. Production of gas, of course, is also declining with the decline in the production of crude petroleum.

The next producing area of importance was the Mount Pleasant field where the first test well was completed on Feb. 8, 1928, and the location was selected by W. A. Thomas, geologist for the Pure Oil Company. Immediately upon the completion of this well, considerable activity began, and a number of other wells were drilled. This field covered a considerably wider area than any that had been previously found, and on May 8, 1931, what is known as the east extension or east pool was discovered. This was drilled in Midland County and had an initial production of 820 bbl. By 1930, the Mount Pleasant district had become the leading oil-producing territory of the state, and several wells were drilled in the so-called east extension, which had a daily production of over 3000 bbl apiece. This field reached its peak production in 1932 and in this year approximately 5,795,000 bbl of oil were produced. Then it began to decline and in 1936 only 880,000 bbl were produced. Total production for this field from 1928, when the first well was brought in, to Jan. 1, 1937, has been 18,869,000 bbl.

Perhaps the next pool of importance was the Porter which is located in Porter Township, Midland County. The Dundee sand was found at a depth of 3380 ft, and soon the outline of this pool was developed. This well was brought in late in 1931 and total production of the pool for that year was 944 bbl; in 1932 it was 7380 bbl; by 1933 it reached 3,354,000 bbl and its peak of 8,317,000 bbl was reached in 1935. This is the largest production that has been obtained from any one pool in a single year. In 1936 production dropped to 4,619,000 bbl, and the total to date is 23,467,500 bbl.

RECENTLY DISCOVERED FIELDS SHOW GREAT PROMISE

Surrounding this particular territory of central Michigan are a number of other relatively small producing areas and the search for oil is constantly going on. Within the last few months a new pool has been discovered which gives promise of being one of the most prolific in the state's history. It is located in Buckeye Township, Gladwin County, which places it slightly north and east of the Mount Pleasant field. At present, two wells having a daily production of approximately 3000 bbl have been brought in. Intensive drilling operations are now being carried on, and soon this pool will be producing oil in substantial quantities, which may be sufficient to restore Michigan to the position that she occupied a few years ago of being one of the principal oil-producing states east of the Mississippi River.

Principal production of oil has been in this general territory running across the center of the state and located around Isabella and Midland counties. However, another field of some importance, which is more or less remote from the central Michigan field, is the territory around West Branch in Ogemaw County. The first production from this pool was in 1933 and to the present time, approximately 1,500,000 bbl has been the result of these operations.

In 1935 a new field was discovered in Crystal Township, Montcalm County, and this proved to be a rather prolific producing field, 3,600,000 bbl being produced in that year. Production in 1936 dropped to about 2,500,000 bbl, and the total for the two years was approximately 6,000,000 bbl. Oil produced in the Crystal field is of high quality, the gasoline being somewhat superior to that produced from the other fields, and it also has excellent qualities for the production of lubricating oils.

The operations which have just been briefly described are the principal ones to date in Michigan. Various small pools have been discovered since the search for oil has become more pronounced, and productions ranging from 500 to 500,000 bbl a year have been brought in from these several locations. Altogether, approximately 32 proved areas have produced quantities ranging from a few hundred to several million barrels during their existence.

The total quantity of oil produced in Michigan, between its discovery in 1925 at the Saginaw field and Jan. 1, 1937, is 66,646,316 bbl, and its value is approximately $100,000,000. Thus Michigan has produced some considerable wealth through the development of this particular mineral resource, and possibilities for a continuation of this activity appear favorable. This total oil production of Michigan is sufficient to supply the needs of the United States for approximately 22 days, based on an average daily consumption of crude oil of approximately 3,000,000 bbl.

GASOLINE YIELD DETERMINES VALUE OF CRUDE OIL

In considering the general subject of petroleum, it is essential that we examine carefully the quality of the oil produced because this is the item that determines the value of the production. In the early days of the industry, the value of an oil was based primarily on the quantity of kerosene that it would yield because in those days kerosene was the major product demanded by the country; gasoline was a drug on the market and frequently drastic means of disposing of it were necessary. Today the situation is reversed.

Naturally, with the automotive industry having reached its present position and with practically everyone driving automobiles and consuming gasoline, motor fuel has for some years past been the product of petroleum that is in greatest demand. Hence today in refining crude oil to obtain its various products, we endeavor to make the maximum quantity of gasoline and only those small percentages of other products which are necessary to supply their particular demands. The result is that in the average refinery operation as carried on today, 65 to 70 per cent of gasoline can be produced economically from each barrel of crude oil whereas in the early days of the industry 25 to 30 per cent was considered a good average production. Most crude oil as it comes from the ground contains a certain proportion of the hydrocarbons constituting gasoline, and all that is necessary in recovering this fraction is to subject the crude to a simple distillation process. The gasoline thus produced will represent 25 to 30 per cent of a barrel of crude oil and is known as straight-run gasoline.

To produce an additional percentage of gasoline from a crude, the residues must be subjected to a cracking process, whereby the heavier, complicated hydrocarbon molecules are split up into smaller, simpler ones having the characteristics of gasoline

and, therefore, coming within the gasoline range. The quantity of gasoline that can be made from a given crude, therefore, determines the latter's value to a great extent. As a matter of fact, the price of crude oil is usually adjusted according to its gravity, which is really an index of the gasoline it contains.

In more recent years, another important factor in the evaluation of crude oil has developed, which involves the quality of the gasoline produced in addition to the quantity. With the development of the modern high-compression engine, certain types of gasoline were found to perform better than others. This is especially true in connection with the tendency of the gasoline to knock or detonate in the engine. It soon became evident that a relationship seemed to exist between this tendency to knock and the chemical structure of the hydrocarbon molecules involved in the fuel. Those gasolines whose chemical structure is principally of the paraffinic or highly saturated type definitely detonate more severely in the engine than do those gasolines whose chemical structure is of the naphthenic or olefinic or unsaturated type. It soon became evident that various crude oils produced in this country could be classified as to their saturated or unsaturated characteristics and, therefore, as to their value as motor fuels.

Pennsylvania type crude oil has been known to be of a highly paraffinic or saturated character, and gasoline produced from this crude has been consistently a hard-knocking fuel. On the other hand, certain crude oils produced in California were of just the opposite nature, and motor fuels refined from such crudes are excellent from the standpoint of their antiknock value. The antiknock value of gasoline is measured in terms of octane numbers, and the average octane number of standard grades of gasoline is about 70. To illustrate the difference between crudes of extreme characteristics, a straight-run gasoline, distilled from Pennsylvania crude, has an octane number of 40, while a similar gasoline, distilled from California crude, would have an octane number well above 70.

Examination of gasoline produced from the average Michigan crude showed that it was still lower in quality, as far as antiknock rating is concerned, than that produced from Pennsylvania crude. The great majority of samples of straight-run gasoline produced from Michigan crude tested as low as 30 octane number. Naturally, a gasoline of this type would not perform with any degree of satisfaction in the more modern engines. For a long time, therefore, Michigan crude was handicapped by the quality of gasoline that it produced.

Cracked gasoline produced from a given crude will have a relatively higher antiknock value than straight-run gasoline from the same crude. This is due to the fact that, in the cracking process, the hydrocarbon molecules produced are usually highly unsaturated and, therefore, have desirable characteristics for a good antiknock gasoline. In cracking residues from Michigan crude, a relative improvement in antiknock value of the cracked fuel was secured, but, with the highly saturated cracking stock from which the gasoline is made, the octane number of the cracked fuel is lower than that of cracked gasoline from other crudes, such as that produced in the Mid-Continent area.

MICHIGAN CRUDE YIELDS SOLVENTS, NAPHTHAS, LUBRICANTS

Therefore, refiners operating on Michigan crude were faced with a definite problem of finding a market for what gasoline it was absolutely necessary to produce, and also of developing other products from this crude which might have a more definite value. As a result, a number of the larger refiners operating in the Michigan fields specialize in the manufacture of special products such as solvents and naphthas. Substantial quantities of the latter are used in the paint and cleaning industries as well as in other activities of a similar nature and considerable quantities are also required as rubber solvents and in the manufacture of varnishes and lacquers. Furthermore, production of kerosene and domestic and industrial heating oils has become a definite item in the use and disposal of crude oil produced in Michigan.

For the production of lubricating oils, Michigan crude has a definite value. Like Pennsylvania crude it produces a large percentage of lubricating-oil stock which has a high quality. Some of these crudes have analyzed as high as 15 per cent of lubricating-oil distillate and 15 per cent of steam-refined stock. The latter can readily be converted into filtered and bright stocks which are the basis for the great majority of automotive lubricating and industrial oils produced and consumed in the country today. The cost of building plants for the manufacture of lubricating oil is relatively high and can be justified only where the source of supply is known to be permanent and of uniform quality. The average refinery operating in the Michigan field is not in a position, economically, to go into the refining of lubricating oils and the result is that even today no refinery which produces lubricating oil from Michigan crude is operating in the state. In recent years, a considerable quantity of crude oil has been transported out of the state by some of the larger refiners who have plants at Toledo, Cleveland, and other nearby points. Probably much of the crude so consumed is converted into lubricating oils at these plants.

Development of oil-producing territory naturally leads to two other activities, operation of refineries for processing the crude produced and of pipe lines for transporting crude from the producing field to refineries. As a result of the discovery and production of crude oil in Michigan, several refineries have sprung up that are designed primarily for producing finished products from Michigan crude. At present, about 20 refineries ranging in capacity from 1000 to 12,000 bbl per day are in operation. The largest is that of the Socony-Vacuum Oil Company located near Trenton, Michigan. This plant, however, operates almost entirely on Mid-Continent crude which is transported to it by pipe line. Occasionally, this plant uses some crude from Michigan fields, but it is not a factor in the processing of Michigan oil.

Several plants are operating in and near Mount Pleasant, one having a daily capacity of 6000 bbl and producing, in addition to gasoline and burning oils, a small quantity of lubricating oil. At first they were simply skimming plants, that is, plants designed simply to distill off the natural gasoline contained in the crude oil. In the last few years, cracking plants have been built at some of these large refineries and a larger percentage of gasoline is now being recovered. This gasoline, as already pointed out, is superior in quality to the straight-run gasoline. The total daily capacity of the plants operating in Michigan is between 50,000 and 60,000 bbl and deducting the capacity of the Socony-Vacuum plant, which does not use any quantity of Michigan crude, the capacity of refineries capable of operating on Michigan crude is between 40,000 and 50,000 bbl per day.

PIPE-LINE, STEAMER, AND RAIL-TRANSPORTATION FACILITIES

Naturally, when Michigan was producing as much as 100,000 bbl of crude oil daily, the refineries' capacity was considerably below this figure, and it was necessary to find outlets for the excess crude through other refinery activities. This necessitated transporting considerable quantities of crude to refineries located outside the state. Where crude oil is transported in any considerable quantity, it is usually done by pipe lines. These consist of an underground piping system, varying from 4 in. to 18 in. in diameter.

When it became evident that Michigan was to be a substantial

producing state, a pipe line was installed from the central Michigan producing fields to Bay City on Saginaw Bay. By this line, oil was carried to Bay City and then loaded in tank ships and transported to such refining centers as Toledo and Cleveland.

Within the last few years, another pipe line running from central Michigan territory to Toledo has been installed. This is an 8-in. line and is capable of transporting a considerable quantity of crude to the Toledo refining center. In addition to these pipe lines, a number of small lines have been constructed from the producing fields to tank farms and to the small refineries located in the producing area.

Crude oil is also transported in large quantities by rail and practically all the finished products are moved by rail, although a limited quantity is transported by truck. Thus, the railroads secure their portion of business as a result of the development of crude oil in Michigan.

In the last few years, cracking plants have been developed which do a fairly good job of producing an acceptable quality of gasoline from Michigan crude, and a few of these plants are now in operation in the Michigan field. When a crude oil of a distinctly different type, as that produced in Michigan, first appears on the market, considerable research work and engineering developments are required to adapt equipment to its processing, this has now been completed as far as Michigan crude is concerned. We may now expect to be able to make products from Michigan crude which are comparable to those produced from other sources.

Petroleum has become a very definite economic factor in the activities of the State of Michigan. As is usually the case, poor farmers who have been struggling along, trying to extract a living from the soil, have suddenly found themselves surrounded by wealth as a result of the discovery of riches in the form of oil beneath the surface of the barren acres. The state itself has been considerably enriched as a result of this industry for much of the oil produced has come from state-owned land. Michigan has experienced, in a small way, some of those things that have happened to other localities.

What is the future of the petroleum industry in Michigan? Some predict that Michigan will be the greatest oil-producing state in the union. I am inclined to think that this is a case where "The wish is father to the thought." On the other hand, more conservative individuals feel that Michigan does not have the possibility of becoming an exceptionally great oil-producing state. They believe that occasional pockets of oil, such as those already described and which are capable of producing perhaps as much as eight or ten million barrels while they are in production will be discovered. They feel that these pockets may be more or less numerous but will be difficult to locate and that, on the whole, Michigan will continue to produce and new fields will be discovered now and then. These will keep the state on the map as an oil-producing factor in this great industry.

Which of these schools of thought is right is not for me to say. I am inclined to be conservative and go along with the latter group, hoping that for the good of our people as a whole, for the good of the state and for the general good of the industry, Michigan will continue to be a substantial producer of wealth in the form of crude petroleum. My hope is that petroleum has definitely joined with salt, copper, iron, and lumber to make Michigan one of the outstanding states in the union from the standpoint of the value of its natural resources.

By John P. Mudd for the Midvale Co.

Work of MECHANICAL ENGINEERS *in* CHEMICAL PLANTS

By JAMES ELLIS

TENNESSEE EASTMAN CORPORATION, KINGSPORT, TENN.

CHEMICAL plants, in common with most others, have work entirely within the province of mechanical engineers. This work would be that having to do with power or with the shop operations connected with maintenance. Another definite place in the chemical industry where mechanical engineers may function with pleasure and satisfaction to themselves and with profit to their employers is acting as the coordinating agency between those responsible for originating chemical processes, and the design of the commercial units to put those processes to work. As industry generally must have more than men and money, so the chemical branch must have more than chemists. An engineer of some sort must assist in transferring the chemist's process from the glassware stage to economical production. This man may well be mechanically trained for the problems are many and varied. They involve to some degree all other branches of engineering, and the training of mechanical engineers appears to provide that breadth of vision necessary to see the problems in a proper perspective.

In discussing the work of a mechanical engineer in a chemical plant we must, of course, say what kind of a chemical plant we are talking about. Almost all industry is tied up in some way with a chemical process, and our chemical friends are always on the alert to find new and different places where they or their brethren may be useful. The type of chemical plant in this discussion belongs to what chemists themselves broadly call the process industries and is, in general, concerned with the treatment of materials so that they change their form or purity and then are shipped somewhere else to be put to final use. Many of the operations are carried out upon liquid chemicals or in processes where liquids occupy an important position. A very definite need exists for some type of engineering thought in these plants, and our purpose is to show that this work can be done well by mechanical engineers, and, further, that in many cases, the mechanically trained man is better qualified to do this work than others.

Naturally, if a mechanical engineer goes to work for an industry that is engaged in putting into commercial operation a new process, a chemist has devised that process. That is his job, and it is generally presumptuous for a mechanical man to tell the chemist how to do his job. Frequently, the mechanical man may feel that choosing the materials of construction is his own work. It should not be, for the chemist is in best position to say what his chemicals will attack.

CHEMICAL-PLANT EQUIPMENT COVERS NUMEROUS CLASSIFICATIONS

Equipment of a chemical plant falls broadly into just a few classifications, among which are the buildings, power and steam supply, refrigeration and temperature control, water supply, materials-handling or conveying machinery, mixing and grinding machinery, drying machinery of various types, distillation equipment, such peculiarly special-purpose devices as autoclaves, and piping. In addition to these, each chemical plant may have machinery unique to that plant or to that branch of the industry. All of these may provide work that a mechanical engineer can do to advantage for his employer. His talents or training should make him valuable as an intermediary between the chemist, who devises the process, and the owner, who expects to make money from it. This last should always be kept in mind. Little reason exists for an owner to build any plant unless he can make money, and, therefore, the engineer has failed if the results do not enable a profit to be made.

In the general classification of chemical-plant equipment, buildings were included. This may seem strange to some. Yet, if a building is required, it must be fitted to some purpose, such as a school, post office, or chemical plant. The chemical industry has few really standardized processes, and frequently, a new building must be designed to house a new process. We cannot look in a book and see what someone else has done, as we can for a powerhouse, but must study what is required and really design an economical arrangement of apparatus and supporting structure.

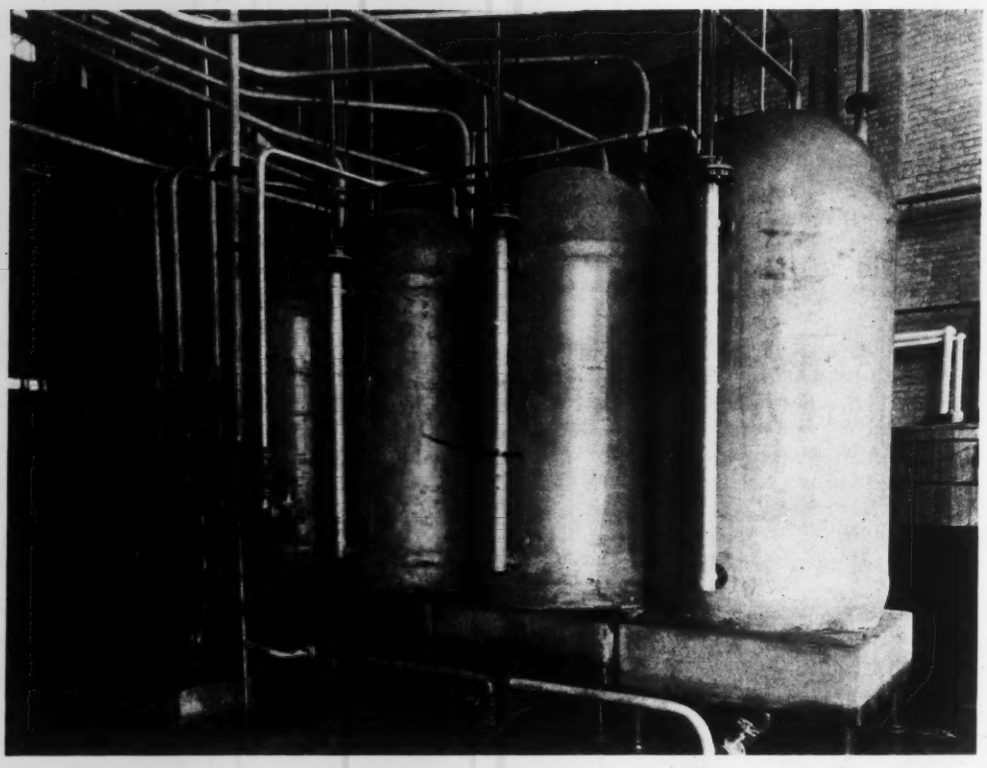
This might well be the architect's work, yet the mechanical man is, or should be, in better position to coordinate the various requirements than the chemist, who is concerned about his process, or the architect, who is interested in appearance, economy of construction, and in the multitude of detail that makes up a building, or the structural man, whose job is primarily that of strength and economy. The mechanical engineer in a chemical plant should train himself so that he can design the building in so far as its general outline is concerned and should have enough knowledge of these other building professions so that he can define the limits to which the architect and the structural man must work. Therefore, he must be versed in building-design considerations. He must know when to use concrete, steel, or wood. He must know, or be in a position to find out, what would be economical proportions for his building. Probable life of the process and the use of the building for other purposes in the future may influence his judgment as to what loadings the floors and columns should be designed to stand.

VARIED PROBLEMS OF MECHANICAL AND ELECTRICAL EQUIPMENT

Practically all of the chemical plants within the scope of this discussion require the use of steam for some purpose other than building heat. There, the mechanical engineer is well within his element, and little will be said here about steam plants or piping for chemical plants. Economical steam-generating pressures must be studied, as well as the possibility of supplying process steam with back-pressure or extraction turbines. Power-plant design for chemical plants may warrant special consideration being given to continuous operation, as this is vital to some processes.

Electrical work in a chemical plant falls in much the same

Presented at a meeting of the Knoxville Section, Kingsport, Tenn., May 24, 1937, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.



PROCESS EQUIPMENT SOMETIMES PRESENTS A STRANGE APPEARANCE

category as buildings, that is, someone must define for the specialists just what is required. At first glance, this problem may appear simple enough just to say that so many motors are located at such and such a place, and let the electrician run wires to them. This is not true, for many other factors must be considered. Choice of motor sizes for chemical machinery, as distinguished from pumps or conveyors, is not easy. In the case of standard machines, the machinery builder has found what size motors are usually used, but he does not always know what use is to be made of his machine, and usually no one else does, if the installation is entirely new.

In addition to steam heat, many chemical operations require reduced temperatures, which means refrigeration. Here, the mechanical engineer should be at home. Air conditioning of buildings is becoming of increasing importance in various industries, and, while it has become specialized, it is essentially a mechanical-engineer's work, and he should be prepared to know what to do. Choice of refrigerating systems is greater now than in the past, and the selection of what to use may require a little more thought and judgment than formerly. Of course, the engineer should see that his employer obtains the system that will be most economical.

At the other end of the scale, some chemical plants require rather high temperatures. Not as high perhaps as those used for metalworking, but too high, in many cases, for steam and usually involving rather close temperature control. Here, he has his choice of burning fuel directly or using liquids other than water, such as hot oil, which may be used up to about 600 F, or mercury vapor, or diphenyl. If the fuel can be burned directly, he again has the choice of coal, oil, or gas. Which of these to use will depend upon the results of study which can be made by the mechanical man as well as anyone. Electric heat is, of course, desirable in many cases.

Another class of equipment is conveying machinery, which for a chemical plant does not differ from that which might be found in a woodworking plant or a coal tipple. The same rules apply, and the same people make them. One problem for the engineer in connection with conveying machinery, which is often overlooked, is to inquire if it is really necessary. That is, will it save its cost in labor in a reasonable time, and, then, what is a reasonable time, considering useful life of chemical plants.

EQUIPMENT FOR MIXING, GRINDING, AND DISTILLING

A class of machinery that is almost exclusive to the chemical industry is mixing machinery. Of course, we have concrete mixers in the building industry and dough mixers in bakeries, but, only in the chemical industry, do we find almost any kind of a device called a mixer and used as such. They may vary from a tank containing a mechanical agitator that stirs two liquids to the heavy machinery that rubber factories call mixers. Just what machine to use in a given case depends upon what is wanted in the final product, the type of ingredients, and upon the personal predilections of the man who makes the selection.

When a chemist speaks of grinding something, he does not have in mind reseating a valve, or making a shaft round and straight, but rather making small pieces from larger ones. The usual devices for accomplishing this are ball mills, such as are used in the cement industry, hammer mills, and attrition mills. Of course, certain problems require other types of machinery, but the principles are much the same. Here, as in the case of mixers, the decision as to what to use is rather indeterminate.

Many chemical problems involve removal of water or other solvent from the material as a final stage in the process. As in the case of mixers, a number of types of driers can be used; sometimes, several can be used on the same problem. We will not undertake to classify these, for fear of starting an argument. The work of the mechanical engineer in this connection is usually limited to making certain that the mechanical features of the machine are satisfactory, leaving it to

someone else to say whether the machine will accomplish the results desired.

Perhaps, the most typical chemical-plant operation is distillation. There are few processes that do not employ distillation in some operation. Distillation, of course, is simply the separation of two substances, usually liquids, by the application of heat. The work of the mechanical engineer in assisting the chemist to set up this type of plant is usually confined to providing proper support and space for the apparatus and bringing steam and water to it. He may, of course, be called upon to compute the size of equipment required, using all the knowledge he can find and then making a good guess at what no one knows. This is all that anyone else would do, for that matter, for, unless exactly the same job has been done before, predicting the specific performance of any individual unit becomes almost impossible.

Many chemical operations employ vessels called autoclaves wherein reactions take place under pressure, usually with agitation or heat, and sometimes both. In connection with them, the mechanical engineer will find that his work is simply to plan the piping to them, although he may be called upon to check their strength.

Piping might have been mentioned along with conveying machinery, for it is the means of moving a type of material from one place to another. While chemical-plant piping is complex, when it is of iron, it is essentially no different from that of a steam plant or a water works. Most of it is for low pressures and generously sized. As a rule, temperatures are constant, so that the problems of expansion do not become of great importance. Inasmuch as the materials handled are worth more than water, piping systems should be designed so that they can be kept absolutely tight. In running pipe lines about the plant, the tendency is to keep them in the open so that leaks can be promptly detected.

When the piping is other than iron, the work is more difficult. Other metals are more expensive, so that the economic problem is to make the piping smaller, usually by increasing the duty of the pumps used.

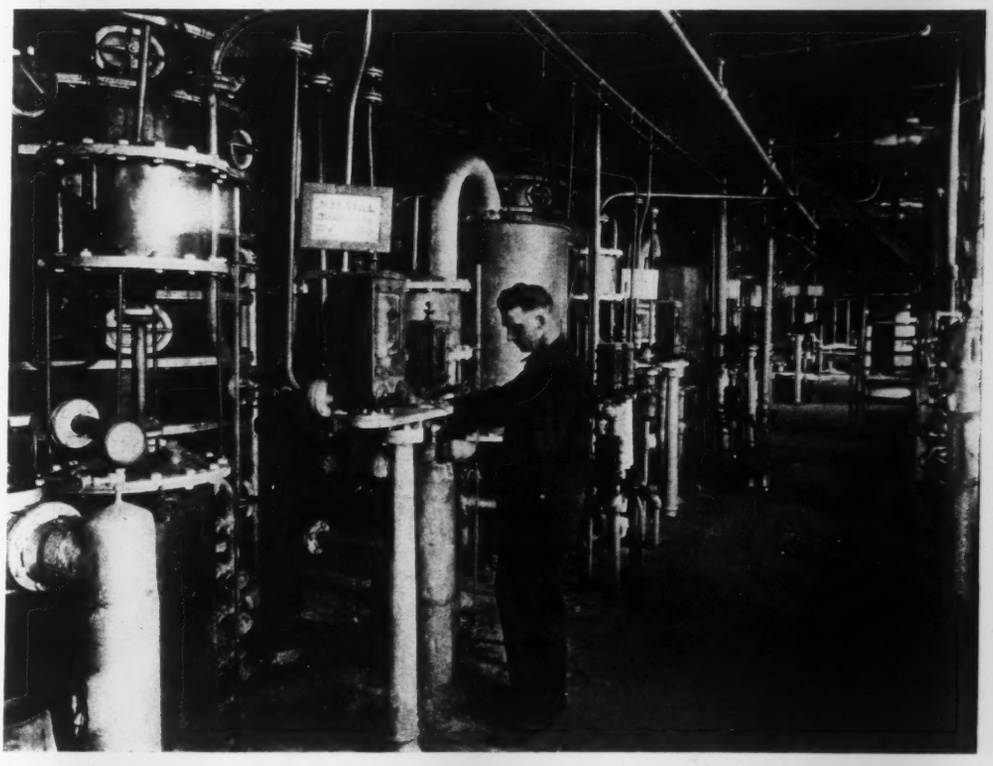
Valves for chemical-plant service are of more importance than for steam or water. In almost every instance, corrosion is greater than with water, and, of course, valves will be affected first. If other than iron, cost will be an appreciable factor, so that much consideration must be given to the material. Again, we cannot consider that any valve will last for the life of the plant, as we might do in a steam plant, for small leaks that would be tolerated with steam are not allowable here.

The principles mentioned in connection with piping apply to pumps. Water pumps, of course, are selected on the same basis as any other water pumps. Possibly, the matter of obsolescence might have more weight.

Application of power-transmission equipment to chemical plants takes a different form from the usual run of factories. As a rule, the line-up of machinery does not permit using line-shafting and belt drives. Where it does, the procedure is, of course, the same as any similar job. Room for considerable ingenuity exists in the application of direct motor drives to chemical-plant machinery, and successful choice of the connection between the motor and the machine is frequently hard to obtain. Several types of apparatus are available for producing variable speed, as well as variable-speed motors. Each of these, no doubt, has its place, and one would be foolish to say that he would always use such and such a type. In discussing drives of any kind, we should always consider whether the service is to be continuous or part time. Naturally, machines that are expected to run all the time should have drives designed for that purpose.

ECONOMIC FACTORS TO BE CONSIDERED

No discussion of anything pertaining to a chemical plant would be complete unless some mention were made of the economic factors. After all, the only reason for the plant's existence is to make money, and, while seeing that the plant makes



DISTILLATION-PLANT PIPING IS OFTEN QUEER AND COMPLICATED

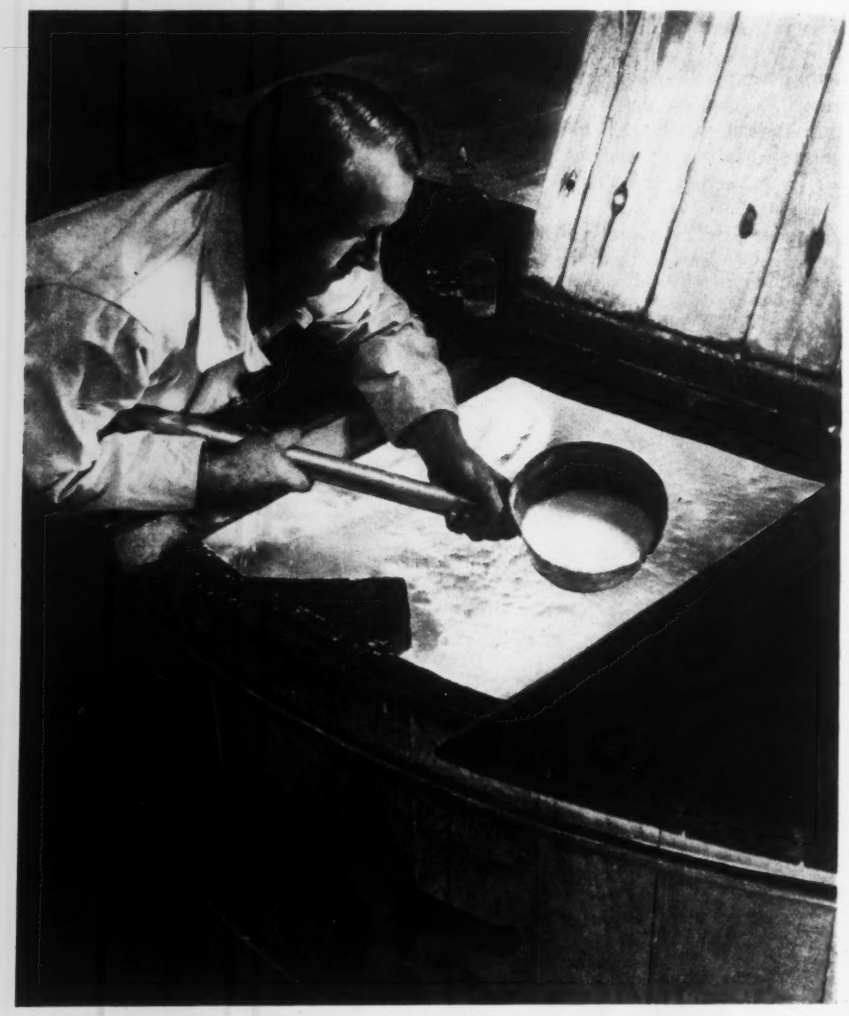
money, is the problem of the management, yet, all those who have anything to do with the building or operation should keep always before them the thought that the operation as a whole must make a profit. This desideratum can be accomplished in more than one way. Sometimes, it is done by specifying the most expensive equipment. At other times, it is done by putting in the cheapest possible installation, perhaps, the one that uses the most labor, simply because the process is not expected to last long. While this problem may not be the specific duty of the mechanical engineer, he should endeavor to see the whole picture and make sure that his recommendations are in line with such a policy. He may not be proud of his work, but, if it makes money, it is a success. The finest of layouts, if it will not make money, is necessarily a failure.

Intimately associated with this thought of obsolescence is the cost of labor. Aside from social considerations, it is obviously of little use to put a complicated automatic device at work unless it will save several times its cost during its estimated life. It is better to spend the money as needed during the life of the process for labor.

Cost of heat and power does not always get the consideration it should. Many are tempted to install heat-recovery devices in localities where fuel is cheap, just because they have heard that someone else does it. At the same time, the effect of a slight saving in the cost of power may be overemphasized. On certain occasions, a pump, for example, might well use a few more horsepower, to accelerate some operation.

Finally, as has been suggested, chemical-plant equipment is not installed with the same permanency in mind as that of a steam plant would be, and we should have ever before us that thought of what we will do with this equipment in the future. Upon occasions, we might spend more for something that we think we can use in the future for another job. This is particularly true of buildings or of extensive platforms installed in existing buildings.

From what has been said, it may appear that a mechanical engineer in a chemical plant is required to be some sort of a wizard who attaches himself like a parasite to a chemist. In a sense, this is true. The chemical-plant engineer needs to take in the whole scope; be a little more versatile than in many other industries, and combine in himself most of the phases of engineering that have lately become specialized and divided. True, he need not know as much about chemistry as a chemist, or as much about building as an architect, or as much about electrical matters as a motor designer, but, somehow or other, he must be familiar enough in all of these fields to coordinate them in a smooth-working and harmonizing organization. A really good artist in this field, for it is an art, might have been trained in any branch of engineering, yet the mechanically trained man is perhaps best qualified of all.



ONE OF THE MANY FORMS OF CHEMICAL-PLANT MIXER

Aims and Objectives of an ENGINEERING EDUCATION

By GEO. A. ORROK

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A DISCUSSION of this subject is, of necessity, colored by the experience of the commentator. If his experience has been solely in the manufacture of cotton goods, he may feel that far too little attention has been paid to textile machinery and that his early education in the technique of air conditioning was woefully weak. On the other hand, if his experience has been with the public utilities, he may look back with regret upon the small attention paid to thermodynamics and possibly regret that more instruction had not been given in electric-power transmission. If his activities had been along other lines, his viewpoint as to the training of an engineer would be totally different. If it were possible to look ahead 10 or 15 years and determine the activity of any present college student, it would be very easy to lay down a course of training that would be particularly suitable to that man's future. It is consequently very difficult to specify definitely the aims or objectives of an engineering training.

Since this must be a personal viewpoint, I can only discuss it on the basis of my own engineering experience. And it is not too much to expect that many of our engineering graduates will meet as wide a diversity of problems as I have met. Although the major part of my activities have been in connection with the generation of power, I have at other times mined coal, prospected for gold, operated cable roads, built underground trolley systems and floating dry docks, and constructed hydroelectric plants, blast furnaces, coke ovens, cement mills, sugar mills, paper plants, and other industrial plants. Since I am asked to answer this question, I can only say that any engineering training must be fundamental in character and as broad as possible and any specification that I might lay down would be necessarily colored by my own engineering education and practice.

HISTORY AND OBJECTIVES OF THE COMMON-SCHOOL SYSTEM

It is possible that I may be peculiarly well-fitted for discussing this interesting subject because, although my activities for the last 50 years have been along mechanical-engineering lines, I did not receive a mechanical-engineering education. In fact, I was not educated as an engineer but spent three years in college, hoping to become a chemist. In entering the engineering field, I found it necessary to do much outside study that might have been done better in college, but, if I have achieved any success as an engineer, it has been due largely to the training in methods of thought and education that I received not only in my alma mater but in the common and secondary schools of the old Bay State.

The object of all education is the making of good citizens. Our common-school system was established by our early Puritan ancestors for this purpose as one of their first activities after they landed on this coast. Three miles to the south of us is Meeting House Hill, on which are located the three schoolhouses now known as the Mather School. This school was founded in 1629 at the first town meeting of the Dorchester settlers who taxed each citizen for the support of the school, the first free public school to be supported by taxation. Roxbury followed shortly after with the Roxbury Grammar School, which was followed two years later by the establishment of Harvard College by the Provincial Government in 1636. The Mather School, though the first public school in America, was not the first school of this type in the world, for the Low Countries had schools supported by taxation before 1620, and it is believed our Dorchester people knew of them. At any rate, the early fathers considered that a citizen should be able to read, write, and cipher, and the three "R's" were well taught at the end of a hickory stick. From these small beginnings our common-school system has grown until today each child gets 10 to 11 years of schooling at the expense of the taxpayer. Our New England school system has spread over the whole of the United States and Canada and the overseas possessions.

Secondary education has grown from the desire for a classical background as a preparation for the ministry. The Roxbury Grammar School early became a Latin school and prepared for college. High schools and academies appeared in New England at the beginning of the nineteenth century, carrying the classical tradition with additional mathematics and later a smattering of the sciences. But most of the work still bore on the duties of citizenship. Since 1870, common and secondary schools have flourished, but, since 1900, the classical tradition has been waning and secondary education has become more and more commercial. Faddism has been rife—tap dancing, clay modeling, sloyd, weaving, music appreciation, and a multitude of arts and fashions have cluttered up the courses of both common and secondary schools. Spelling has become almost a lost art. Far too many sweet girl graduates spell "such" with a "t." Geography and history have degenerated into story-telling, and a few there are, indeed, who know the towns and counties of their own state, while many high-school graduates cannot add accurately a column of figures without an adding machine. Penmanship, which became legible in the 60's and clear in the 70's and 80's, has now, under the influence of the typewriter, gone back to the illegibility of a century ago. Euclid has been superseded by the so-called "modern school" which Lewis Carroll preached against in a book not so well known as "Alice in Wonderland." That engineers are produced from such material is a wonderful fact, and it is also wonderful that good engineers have been developed apart from the present educational schedule.

WHAT PROSPECTIVE ENGINEERING-STUDENTS SHOULD KNOW

The first essential for a good college course in mechanical engineering is a class of boys well-trained in our common and secondary schools. They should be able to read at sight, easily and well. If they have been taught properly they will read fast, say one hundred 16mo pages per hour. They should have mastered the arithmetic, be able to add a column of fig-

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ures, and have mastered high-school algebra, geometry, and trigonometry. They should write a legible hand, spell reasonably well, and write good English freely. They should be familiar with many good examples of English literature, including Shakespeare and the King James version of the Bible. They should have a working knowledge of American and English history, be able to distinguish between Roman law and our English common law, and be familiar with the Constitution of the United States, the state constitution, and the systems of town and county government. In geography, they should know their own county and state and the United States, draw memory maps with natural features, have a general idea of altitudes and distances and of locations of important cities and ports and railroad, steamship, and air lines. And this should not be too much to gather from 13 to 15 years of schooling at the expense of the taxpayer. If, in addition, the candidate can offer a reading knowledge of one foreign language, this is the least we should ask from the public-school system.

But this is not all the candidate should present. Between three and four years of this school time are *vacations*, for recuperation from the arduous work of the school, for games, travel, and similar recreation. Is it too much to ask that the boy should have worked at one or two mechanical trades, in business, in manufacture, or even in an automobile service station? He should offer some manual dexterity as a part of his preparation for life. No amount of athletics, popularity in prep-school activities, or plausible journalistic experience can substitute for the manual dexterity and experience of earning a livelihood which comes from actual work with workmen.

The college entrance examination should insure to the colleges this sort of material, and it should not be boys but men. Maturity does not come to everyone at the same age, and many of our failures are due to the boy's not finding himself before he has his real career to make or mar. When Rogers was asked where Tech allowed time for play, he replied that Tech was a place for men to work not for boys to play, and yet I remember that we did play, some.

As I look back on a college without dormitories and compare it with the dormitories of that time and even of a few years ago, I reflect on the serious views concerning life, work, and recreation which many of my friends expounded between periods, in the laboratory, and on our way to school. Once in a while, we did break loose. But our distractions were normal and mainly had been overcome in the boyish stage and put by when we began to pay for our education. Most of us were there to prepare for a lifetime of work, of altruistic endeavor and good citizenship. And with this sort of a preparation what must the college teach so that the graduate may quickly and readily apply his knowledge to the acquiring of the art of engineering?

FUNDAMENTAL PHYSICAL LAWS THE BASIS OF ENGINEERING

I think we may lay down as a principle that engineering is an art founded on scientific principles or the fundamental sciences. Engineering cannot be taught in school, since the art must be acquired by practice. The underlying principles can be taught in school, leaving the art to be acquired by practice after graduation. And since engineering may be defined as the utilizing of the forces of nature for the benefit of man, the fundamental physical laws are the basis of engineering. We term the science of the laws of nature, physics, and this name is as good as any other, although natural philosophy had a long and distinguished reign.

This science called physics can be taught from books, by precept, and in the laboratory. Each problem can be presented simply, and the sum is a mighty structure embracing the universe and is the real foundation upon which the art of engineering stands. We have drawn a distinction between where the working substance maintains its identity, i.e., physical change, and where its composition is changed to make other substances, i.e., chemical change. And thus, we have another science, chemistry, but so closely allied that the combination might be known as physical chemistry; and both phenomena are in reality one. In fact, it is difficult to draw the line and, in my opinion, impossible.

In the large domain of physics and chemistry, physical chemistry, natural philosophy, engineering science, or whatever the nomenclature be, there are many roads to knowledge, but they are interwoven in a network and interconnected so that segregation is most difficult. Mark Twain tells a most amusing story about his first visit to Boston and how he tried to follow the tracks of Master Blackstone's cow. The would-be acquirer of an engineering education has the opposite experience for, as his study intensifies, he finds new vistas opening out on all sides and all barricades and entraining walls are man made, artificial, introducing troubles of understanding for the inquiring mind.

This subject of natural philosophy, to go back to the ancient name, has gradually acquired a language of its own, and the natural laws, chemical reactions, crystalline forms, atomic latticeworks, and the interrelationship of nucleus and electron, proton, or neutron is now formulated mathematically. The pure mathematicians may not like this characterization but mathematics applied to physics, chemistry, and their byways is the third fundamental subject making up engineering science.

"SUBJECT" COMPLEXES AND THEIR EFFECTS UPON STUDENTS

It is most unfortunate that we have inherited a "subject" complex. We have specialized early and often. The boy in the primary school says, "No! I can do vulgar fractions but decimals don't come in this grade," and "I can do decimals but we won't take percentage and interest for two years." Both children had been earning money and spending it, but that "subject" had not been taught, and it has never been pointed out to them that there was no difference, except the name, between a vulgar fraction and a decimal or a percentage. The designers of this system may be classed with Sewell Ford's professor who wore a cedar bucket on his head to keep out the decimals.

State Boards of Education fix a pattern of subjects that can be passed in detail, one by one, and forgotten before the end of the course, and technical schools are prone to follow the same practice. "I have just passed descriptive geometry and, next year, we take stereotomy," but a good old-fashioned tinsmith will lay out an intricate mold form on the flat tin, and, when finished, it will be true to form and dimension. The calculus, according to John Perry, is a method of thinking which can be acquired by children of ten with advantage, but many holders of an engineering degree never have acquired this method of thinking. This tendency is present in the teaching of physics and to some extent in chemistry.

It is my contention that these subjects, these watertight compartments, to be begun, finished, and passed off in a semester and then forgotten, do the potential engineer little good and add little to the mental discipline to which he should have been subjected in the lower schools. It is also my contention that engineering science (physics, chemistry, and engineering mathematics) can be taught as one continuing, broadening foundation to classes of young men seeking an engineering education.

What does this mean to the engineering courses? First, that engineering science is taught throughout the course along the three major lines of mathematics, physics, and chemistry by

lecture and text, classroom and laboratory, interwoven together, reiterated, principles first, then applications, and passing from the general and descriptive to the particular and quantitative. This emphasizes the graded course, the very best teachers taking the first-year courses and laboratory, while the older classes get more of the assistants and instructors, in order that the foundation may be good and sound. Of course, it would be ideal if all professors, assistants, and instructors were of uniformly high grade, but we can only hope for a modicum of this. We know we will have a graded group of students and that some will fall by the wayside, but the teachers should be the best possible.

Mathematics, the language of engineering, should be taught as a tool, not as an end. Much engineering is possible with little mathematics, just as a good mechanic can turn out a good job with poor tools, but it is so much quicker and better done with good tools. The engineer with the capacity to use this tool has a great advantage and can go swiftly and surely over much that would otherwise be slow and difficult. Many engineers go so far as to say that mathematics should be taught by engineers and not mathematicians, but I think there are many mathematicians who are interested in seeing how far-reaching and workable a tool their science may create. We have many teachers today who put life into the dry-as-dust formularies of calculus, quaternions, least squares, spinors and tensors, and similar subjects and can use them as tools to solve old problems and formulate new theories.

In the days when I was a student under Pickering and Nichols across the river, the work on physical chemistry had begun, but, in the secondary schools, they were still using Steele's "Fourteen Weeks in Physics" and its companion textbook in chemistry. Later, these were the prescribed textbooks that I had to teach from both in this state and in the West. There were other texts on astronomy, botany, and other "subjects," each designed to run through a term. But even in those days there were teachers who had seen the light, and my own lines were cast under men of catholic taste and genius. Cross, Drown, and Crafts showed us that, while the distinction between physical and chemical changes was the picket fence at that time, the pickets were as far apart as they were wide.

PHYSICAL CHEMISTRY AND ITS MATHEMATICAL LANGUAGE

Though this happened 50 years ago, the problem still is with us, and in many places the pickets are laid solid and the "subject" idea still persists. I contend that it is possible to teach as one identity the physical chemistry of our universe with its mathematical language, to place the ideas in the minds of our first-year men, and to train them in the facts, laws, and workings of our material world so that they may use them as the basis of the art of engineering which they will acquire after they enter the practical world on graduation.

Some years ago, at a "steam table" discussion, when we were trying to develop a plan of campaign for the prosecution of the research, I listened to two men, one a physicist and the other a chemist, talking mathematics in planning the apparatus for their work. Both of these men are engineers. Each of these men has done work of high quality in engineering, and I can recall not more than a dozen other engineering conferences where the participants knew so well what they were talking about, expressed their views so clearly, and arrived at an engineering decision that the course of time has proved to be correct and adequate. We have heard many engineering discussions neglect essentials of chemical or physical law, forget that mathematics is a tool and not an end, and end in failure and much tribulation. History is filled with engineering failures, where one or another of these essentials has been neglected. But they are taught as "subjects" in watertight compartments, and, as with vulgar fractions, decimals, percentage, and interest, no one has been interested enough to show that they differ only in name. So let us teach physical chemistry and its mathematical language as one subject, principles, laws, and applications, name the subdivisions as you please but point out every day, every hour, that this is one broad highway without bulkheads or fences but do not stray too far out on the shoulders.

This first division should take up three periods throughout the entire course, the last year or two embracing more of the applications than the earlier years and leading to what might be called the solution of practical problems. Years ago, I found, in a secondhand store, a set of notes on applied physics used in l'Ecole des Arts et Métiers by Professor Ser. He seemed to be far ahead of his time, it was dated 1863, and I used it as a guide along with a French copy of Reuleaux's "Constructeur" for a handbook for many years. Both volumes abounded in problems that would be called practical.

LANGUAGES' PLACE IN ENGINEERING EDUCATION

Besides the groundwork of the fundamental sciences and its language, the study of English should be continued, and the work of secondary schools should be supplemented by reading and writing, using the entire collection of the humanities as they are listed in academic courses but with a different method. History of civilization, of peoples, of engineering so intertwined with the study of words and good diction, with criticism and composition, with logic and rhetoric, and even with music and prosody, so that the body of fact will be appreciated and retained, while the shibboleth of terms and definitions and the paraphernalia of the schools may be relegated to a very minor position. Economics, not the classical political economy and psychology, without the extensive and blatant terminology upon which few agree, may well enter into this same classification as English, and even poetry may play its part in the general plan. This category will cover the fourth period throughout the four-years' course.

The fifth period should also be given to language—to the securing of a sound reading knowledge of French and German. Much valuable material can be found only in these languages, but I believe it is idle to try to impart a speaking acquaintance with either tongue in a technical school. A reading knowledge, when taught properly, is easily attained in French and not so easily in German. There are good textbooks, reference books, and periodicals in both languages, which should be within the compass of the technical school, and these books can be used as material to acquire the vocabularies necessary to the understanding. Translation is an easily acquired trick, unless many invented words are used, and the grammatical forms are not difficult. Involved writers are to be avoided, but, as in English, the best writers are the easiest to understand.

Here again the greatest trouble will be to find teachers of English, French, or German who can concentrate on teaching language as a tool of engineering and not as an end. I early discovered my French or German friends wrote me always in their own tongue but preferred my answers to be in English. Dr. Rateau, for instance, considered my technical French good enough for translating his contributions to The American Society of Mechanical Engineers into English for publication in the Transactions but much preferred I should write him in English. I consider attempting to teach a speaking knowledge of a foreign tongue in college a wasted effort both for the teacher and student. But reading can be taught and with little difficulty to all.

We have now preempted five periods throughout the whole four years. We have taken 30 hours per week or more if the

laboratory and drawing room time is extended to 4 hours. The time left for study is small if the ordinary system were used. But, when the graduate starts work, he will put in 35 to 40 hours on the job, and, if he is going to be an engineer, he may spend another 25 to 30 hours outside in study, reading, or looking up for the next day. Few rising engineers work less than 60 hours per week, if they are thinking of the work they are doing. Those who learn easily may pull through with an 8-hour day. For the many who find concentration difficult, 11 or 12 hours will be necessary, but the end is worth the work.

It has been usual to grant a degree for an equivalent of about 18 full courses, four and a quarter full courses per year, and electives and snap courses might make up half the count. Some technical schools give a degree on the equivalent of 24 full courses over a six-year course.

I believe that with proper teachers and well-prepared first-year men, 20 full courses of the type I have put before you is a better preparation for a science degree in engineering than the 24 courses as ordinarily offered. The man will work harder, but, when he gets through, he will be prepared to pick and choose, and, wherever he goes, it will be to him that the good work is given, always providing that he has the other necessary qualifications for a life of usefulness in engineering work.

ENGINEERS MUST CONSIDER THEIR WORK NOT THEIR CAREERS

Kipling, in his autobiography, tells a story of Cecil Rhodes. A young officer at the dinner table asked Rhodes what he thought of him and his career. Rhodes postponed the answer till the end of the dinner and then, in his characteristic voice, laid down that the young man would eminently succeed but only to a certain point, because he was always thinking of his career and not of the job he was doing, which time proved to be true. Engineering is a jealous mistress. She requires a detachment from all things except the particular work of the moment. If a young man goes into engineering because he loves the work so much he can do nothing else, he is on the highroad to success as an engineer. If he is thinking of the rewards or a monetary success, he will go into the sales end or management or business. The kind of material to be desired is the man who sees the job to be done for the benefit of mankind. Material success is incidental. A good job well done is its own reward. This type of material, if he has the engineering aptitude, will take to a course of this kind with the zest of the enthusiast. The precedents of engineering have been put before him in his five courses, and teachers with a flair for engineering can turn the work into play with the best of results.

This is no new proposition. Perry and Ser practiced it, as well as many others, more than a half century ago. But the necessities of classification, the planning by pedagogues and politicians, the "normal method," the craze for passing off "subjects" by examination, the teaching of subjects by specialists, and departmental jealousies have all combined to prevent the spread of the idea. The writers of textbooks must take some of the blame along with the demands of industry, which for a long time asked for specialists and expected the schools to produce the impossible. Today, industry is seeking the men with a broad foundational training and sound reasoning capacity and is schooling the new helpers in the art of engineering in their own organization.

There are few Millikens and Eddingtons, few Perrys and Thurstons, but in my own school I look back to Nichols, Pickering, and Drown, none of whom could keep to his own subject in lecture or out. They tied in for me the laws of the Big Three, as I may call them, while Dewey, just new caught, as it were, mixed all three with economics, his own subject, and dabbled in English, French, and history. President Walker mixed his economics with sociology and engineering, with politics and government. And we worked and liked it.

Going back still further to my early days at the Mather School brings up Edward Southworth, master and one of the originators of the Quincy method, who despite the administrative duties of a school of 1500 pupils found time to teach arithmetic, the Constitution and civil government, the duties of a citizen, and history of civilization to the ninth grade. He led us just as far as we would go, and it went much beyond the prescribed limits of the grade. C. A. Fearing, who was supposed to teach English to the mechanic-arts students, used historical, mathematical, and engineering texts as the core of his lectures and our compositions, as they were called then, and even Luquiens, the French professor, afterward at Yale, used technical papers and Jules Verne instead of Mollière, Victor Hugo, and Racine for reading lessons. He wanted quantity and accuracy instead of idioms and the classics.

PLANNING ENGINEERING COURSES A TEACHING STAFF'S FUNCTION

In planning this address I had in mind the working out of a table of courses for the four years of college. Further consideration shows that this is a function of the available teaching staff and their methods of imparting the basis of natural law to the youthful mind. For any given group of teachers this would be possible, but I believe it would be rare that two sets of men would teach from the same formula. Compare, for instance, such men as Peabody, Spangler, Sidney Reeve, and Good-enough. Each taught well, but their methods were as wide apart as the poles. Or compare the methods of Whitham, Cooley, and Hollis, graduated from the same school at about the same time and assigned to the teaching of mechanical engineering. Or to go farther back, compare such famous men as Hirn, Riedler, Dwelshauvers-Dery, Osborne Reynolds, or Unwin by the trail of their successful pupils who have blazed their teachers' fame to the skies. No one scheme could fit these diverse and engaging mentalities whose work has been so fruitful.

But our latest slogan, the planned economy, has set out to plan industry, business, housing, the style and cost of living, and, no doubt, it will attempt to plan for our schools and colleges. The "normal method" attempted to do this for the grammar and secondary schools. The towns have given up the conduct of these schools to the state boards of education in return for state aid and in the interest of standardization, and the colleges themselves have standardized by the College Entrance Board examinations. We are told that the problem is so complicated that our only salvation is a standard control of schools by a national authority, and we are referred to the schools of law and medicine as examples of what good control can do. The engineering profession has license requirements in 34 states, but these licenses to practice are not given on graduation, as in the case of the schools of law and medicine. It does not appear that these ideas and practices, up to date, have been productive of either uniformity or excellence, for we have failures and successes in about the usual proportion.

During the last 70 years we have had men entering college and benefiting from real teachers, poor teachers, and just professors, and we have had other men who wasted their money and time, men whom even the good teachers could not enthuse. What we need today is young men, well-prepared, well-read, well-trained, and eager to absorb the many good things set before them. And we also need teachers who can teach, lead, and enthuse the young man, who can hold his attention, 'mid the thousand and one new distractions unknown to the older generations and even put the fear of God in his eyes before he enters as a beginner in the field of mechanical engineering.

THE ENGINEER *and the* ISSUE *of* SECURITIES

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PROVISIONS OF SECURITIES ACT

THE SECURITIES ACT was passed in 1933 and was the direct result of the agitation against the unregulated public offering of new issues of securities which boiled up after the very heavy losses suffered by investors in the market decline in 1929. The principal provisions of the Act provide, in effect, that, with certain exceptions, no public offering of a security involving interstate commerce or the use of the mails shall be made by the issuer or by an underwriter unless a so-called "registration statement" has been filed with the Securities and Exchange Commission containing a mass of information about the issuing corporation, its officers and directors, the underwriters, and the terms and purposes of the offering, and until the registration statement has become effective. This takes place automatically twenty days after the registration statement has been filed with the Commission, unless the Commission enters a stop order, because it believes that an untrue statement of a material fact or an omission of a material fact may have been made in the registration statement as filed.

No definition of the term "public offering" is contained in the Act, but, as construed in the opinions of counsel for the Commission, it has an extremely broad meaning and includes not only everything which the layman would consider to be a public offering but many other things besides. For example, the sale on a stock exchange of a few hundred shares of stock is considered a public offering and so is the sale of securities by a corporation to its stockholders or the sale of securities at auction. On the other hand, a stock dividend is not a public offering because it is not a sale, that is, no value is received by the corporation from its stockholders. The term "underwriter" is not used in its ordinary business sense but is given a very much broader meaning. In substance, an underwriter is defined as anyone who has purchased from an issuer with a view to, or sells for an issuer in connection with, the distribution of any security or who participates, directly or indirectly, in any such undertaking but does not include a person whose interest is limited to an ordinary selling commission received from an underwriter or dealer. To determine whether or not a person is an underwriter, the term "issuer" is defined to include a person controlling, controlled by, or under common control with the actual issuer. The Act also requires every underwriter and every dealer, for a period of one year after the public offering, to deliver a prospectus, in the form required by the Act, to each purchaser of the securities.

The liability imposed for untrue statements and omissions in the registration statement, commonly called Section 11 liability, in its original form was so severe that it was generally considered to have prevented many issues of new securities, and, as a result in 1934, the liability provisions were somewhat modified. Nevertheless, the liability imposed by Section 11, as amended, is still very severe and has greatly extended the liability imposed at common law. In substance, Section 11 provides that the issuer, the principal officers of the issuer, all the directors of the issuer, the underwriters, and any expert who, with his consent, is named as having prepared or certified any part of the registration statement or as having prepared or certified any report or valuation which is used in connection with the registration statement shall be liable if there is any untrue statement of a material fact or any omission to state a material fact required to be stated in the registration statement or necessary to make the statements made not misleading. In the case of the expert, his liability is limited to the statements in the registration statement, report, or valuation which purports to have been prepared or certified by him. I have used the term "expert" because that is the one generally used, but the exact language of the Act is: "Every accountant, engineer, or appraiser, or any person whose profession gives authority to a statement made by him." The liability runs in favor of any person who acquires the security, either at the time of the public offering or in the open market, and any such person may recover as damages the difference between the price paid for the security, but not more than the public offering price, and the then price of the security, provided that such damages shall not be recoverable if, and to the extent that, the defendant proves that they were not caused by the untrue statement or omission. The Act also provides that no action shall be maintained to enforce this liability unless brought within one year after the discovery of the untrue statement or omission and within three years after the security was bona fide offered to the public.

In any such action, the issuer cannot avoid liability even though it shows due care or lack of knowledge, provided the purchaser of the security shows that there was an untrue statement of a material fact or an omission to state a material fact required to be stated in the registration statement or necessary to make the statements therein not misleading. However, an officer, director, or underwriter will not be liable with respect to statements not made on the authority of an expert if he proves that he had, after reasonable investigation, reasonable ground to believe and did believe, at the time the registration statement became effective, that the statements therein were true and that there was no omission to state a material fact. An officer, director, or underwriter is not liable with respect to statements made on the authority of an expert, if he proves that he had no reasonable ground to believe, and did not believe, that the statements were untrue or that there was an omission to state a material fact. An expert is not liable with respect to statements purporting to be made on his own authority as an expert if he proves that he had, after reasonable investigation, reasonable ground to believe, and did believe, at the time the registration statement became effective,

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that the statements therein were true and that there was no omission to state a material fact.

In the first instance, the burden of proof is on the purchaser of the security to prove that an untrue statement of a material fact or an omission of a material fact was made in the registration statement, but, if he proves that such an untrue statement or omission was made and that he has suffered damage, the burden of proof then shifts to the defendant. To escape liability, the defendant must then prove that the damage was not caused by the untrue statement or omission or must prove that, after a reasonable investigation, he had reasonable ground to believe that no material untrue statement or omission was made or, in the case of statements made on the authority of an expert, that he had no reasonable ground to believe that the statements were untrue or that a material omission was made. This last defense is not available to the issuer. The practical effect of the imposition of this burden of proof upon the defendant, which is contrary to the ordinary rule at common law, is hard to predict. Certainly in some cases, at least, it will be extremely difficult for the defendant to sustain this burden of proof, particularly as the final decision on this point will in most cases be in the hands of a jury.

Another provision of the Act makes any person who sells securities, in interstate commerce or by the use of the mails, liable to the person who purchases from him, if such sale is made by a prospectus or oral communication which includes any untrue statement of a material fact, or omits to state a material fact necessary to make the statements, in the light of the circumstances under which they were made, not misleading. The seller is relieved of liability if he sustains the burden of proof that he did not know, and in the exercise of reasonable care could not have known, of the untruth or omission. This provision is included in Section 12 of the Act; liability arising under it is commonly referred to as Section 12 liability. As a practical matter, it probably does not greatly increase the liability which exists at common law.

The Act also provides that every person who, by or through stock ownership, agency, or otherwise, controls any person liable under Section 11 or Section 12 shall be liable, jointly and severally, with and to the same extent as such controlled person, to any person to whom such controlled person is liable, unless the controlling person had no knowledge or reasonable ground to believe in the existence of the facts by reason of which the liability of the controlled person is alleged to exist. Because of this provision, a parent corporation may be liable by reason of an untrue statement or omission in a registration statement filed by one of its subsidiaries. However, this liability is not confined to cases where the controlling person owns a majority of the voting stock but arises whenever any form of actual control is found and may, therefore, exist in a variety of different situations.

PROVISIONS OF SECURITIES EXCHANGE ACT

The Securities Exchange Act was passed a year later than the Securities Act and was ostensibly directed at regulating stock exchanges. Actually, it covers a very much broader field, although most of the provisions purport to be connected in some way with the stock exchanges. They relate to the exchanges themselves, members of the exchanges, transactions which use a facility of an exchange, listed securities, corporations which have listed securities, or officers and directors of corporations which have listed securities. This Act not only regulates the stock exchanges but also is intended to prevent excessive speculation, to obtain current information about all listed securities, and to prevent manipulation.

The Act gives the governors of the Federal Reserve System power to fix the minimum margin requirements which the members of any exchange shall require their customers to maintain, and to regulate the extension of credit by banks and other persons for the purpose of purchasing or carrying listed securities. There are stringent provisions which are intended to prevent manipulation and pool operations in listed securities, and a provision that no proxy, consent, or authorization relating to a listed security may be solicited except in accordance with the regulations of the Commission.

Another provision imposes on a director or officer of any corporation which has a listed equity security and on a holder of more than 10 per cent of any listed equity security of a corporation the duty to file monthly statements of all transactions in equity securities of the corporation and to account to the corporation for any profits which he may make from purchases and sales of the equity securities of the corporation if such purchases and sales take place within six months. The constitutionality of this provision is very doubtful, and it is very ambiguous on a number of points. However, until it is judicially interpreted, the practical effect is to prevent any such director, officer, or 10 per cent stockholder from making any purchase of an equity security of such corporation unless six months have elapsed since his last previous sale of such security at a higher price and from making any sale of an equity security of such corporation unless six months have elapsed since his last previous purchase at a lower price.

Another provision of the Act gives the Commission power to require the registration of all brokers and dealers who engage in over-the-counter transactions involving the use of the mails or interstate commerce. Use of manipulative, deceptive, or other fraudulent devices or contrivances in over-the-counter transactions is forbidden, and the Commission is given the power to define such devices and contrivances.

Liabilities under the Securities Exchange Act are chiefly criminal. However, civil liability is imposed on any person who makes or causes to be made any statement in any document filed under the Act which statement is false or misleading with respect to any material fact. In the case of reports filed by a corporation, the officers who prepare and sign the reports are apparently liable, but the liability, if any, of other officers and of directors is uncertain. Until decisions have been rendered, the safe course is to assume that they may be liable and to act accordingly. This liability runs in favor of any person who, in reliance upon the false or misleading statement, shall have purchased or sold a security at a price which was affected by the statement, and any such person may recover the damages caused by such reliance, unless the person sued proves that he acted in good faith and had no knowledge that the statement was false or misleading. This liability is very different from that imposed by the Securities Act, notably because it requires that the person suing shall have relied on the false statement; and because the person suing apparently has the burden of proving that the price of the security was affected by the false statement. It also differs in that the person sued is not liable if he proves that he acted in good faith and had no knowledge that the statement was false and is not required to prove that he made a reasonable investigation and had reasonable ground to believe that the statement was true. On the other hand, the liability runs in favor of people who sell securities as well as to people who purchase securities.

REGISTRATION STATEMENT PROBLEMS

So much for a summary of the Acts. We can now turn to the practical problems which face officers and directors of corporations in complying with the Acts. Let us suppose that a corporation wishes to raise new capital through the

sale of its securities. Whether the securities are new or have been held in the treasury or whether they are being sold to stockholders or through investment bankers to the public makes no difference. The first step must be to prepare a registration statement. Several different forms are used for different types of corporation and situations, but the principles involved in all the forms are substantially the same. However, the form which is used in the great majority of cases is form A-2, and I shall comment on that form exclusively. The questions are grouped under the following headings: Organization, History and Business, Capital Securities, Description of Securities, Underwriting, Proceeds and Their Application, Management and Control, Recent Sales of Securities by the Registrant, Options, Miscellaneous, and Historical Financial Information. In addition, certain financial statements are required.

Questions under the heading Organization are routine, and the only one presenting any difficulty is that calling for the names of all parents. Since a parent is a person in actual control, regardless of stock ownership, this question is sometimes difficult to answer.

Questions under the heading History and Business are probably of the greatest interest to engineers. They are simple enough in form, since they merely require a description of the business of the issuing corporation, any material developments in its business during the last five years, and a description of its principal plants. If the corporation has franchises, a description of the principal ones is also required. At first glance, this appears very easy, but, unless the business of the issuing corporation is unusually simple, a number of difficult problems will develop. In this connection, bear in mind that liability may arise not only from an untrue statement but also from the omission of any material fact necessary to make the statements made not misleading. Probably, the most difficult problems arise in connection with determining what collateral information must be included and what can be safely omitted. A few examples will make this clear. They are supposititious but are, nevertheless, based on actual problems which have arisen in recent months.

Suppose that the issuer is a manufacturing corporation and sells 5 per cent of its entire output to each of ten customers. Is this a material fact which should be included? Most persons probably will say that it is not. However, if, a year later, the issuing corporation has lost five of the ten customers and has been unable to obtain others so that its business has been proportionately reduced, convincing a jury that a material fact had not been omitted from the registration statement might be difficult. Does it make any difference if it sells 10 per cent of its entire output to each of five customers or 25 per cent to each of two customers? In actual practice, in one form or another, this is a very common problem.

Here is another example. Suppose a corporation obtains an engineer's report on its business, not for the purpose of, or in connection with, a proposed sale of securities, but because the directors wish to have an outside check made to determine whether the business is being managed in accordance with the best modern practice and the latest developments in the industry. The report is intended for the officers and directors not for general publication. The engineers are more forceful in their expression than they would be in a report that was to be made public. Recommendations are made without qualifications, because they are considered unnecessary in view of the knowledge that the officers and directors have of the business. The report recommends drastic changes in the conduct of the business and predicts a sorry future if they are not made. Nevertheless, the recommendations are not adopted for reasons which the directors deem sufficient. Suppose, for example, that developments take place which, in the opinion of the directors, make the recommendations of the report no longer applicable or that the directors, after careful consideration, come to the conclusion that the recommendations in the report are wrong. Six months or a year later, the corporation decides to sell securities to the public. Is it necessary to disclose in the registration statement the existence of the report or the recommendations made in it? Does it make any difference if the engineers who made the report object to its publication because it was not prepared for that purpose, although they are not willing to change or supplement the report in any way? Under these circumstances, to require that the report be filed with the registration statement and referred to in the prospectus may seem unfair to the issuing corporation, and, in fact, the report may really be misleading. Nevertheless, I do not believe that anybody would be willing to take the risk of not filing it or not referring to it in the prospectus since convincing a jury that the omission was justified would be almost impossible, if the value of the securities should suffer a marked decline within a year or two after the public offering.

Let me give one more example. Suppose that a new method of manufacture is in process of development and that the issuing corporation has not made any plans to adopt the new method, although many of its competitors have abandoned the old method and adopted the new. Suppose the management has carefully considered the new method but, because of the particular situation of the issuing corporation, honestly believes that it will operate more profitably using the old method or that waiting for further developments before reaching a final determination is desirable. Suppose that the shift will disrupt the business for several months or will require large capital expenditures. To what extent is describing the new process or attempting to predict its effect on the industry and on the business of the issuing corporation necessary? Certainly something must be said, and it is extremely difficult to determine the exact form of such a statement and what its contents should be.

These are not unfair examples; the problems which actually arise in practice are much more complicated and more difficult and of every variety. For example, what should be said about obsolescence; competitive conditions, either in the industry or with other industries; efficiency of management; labor conditions; tariffs; oil and ore reserves; expiring patents; taxation; new legislation; and so on.

ENGINEERS' REPORTS

Many of you, either as independent engineers or as officers of corporations, will be called upon to make reports on the business of corporations that are about to issue new securities. I warn you to be extremely careful as to what you say in such reports. Certainly, no one wishes you to say anything in such a report which is not entirely in accord with your best judgment and your honest belief. However, do not be carried away by a desire to prove your point so that you say more than you actually mean. Every lawyer who has worked on a registration statement likes to have the statements that are made with respect to the property and business of the issuing corporation supported by expert opinion, but the experienced lawyer awaits the report of the expert with considerable fear and trembling. Rare indeed is the report that does not contain some statement which shows the fear to have been justified. You may have noticed or may have signed the short certificate which appears in many registration statements to the effect that, in the opinion of the signing expert, the statements made

in the items of the registration statement relating to the business and property of the issuing corporation are true and that no material fact is omitted. One important reason for the use of this form of certificate instead of a complete report is to avoid the complications which may arise from an unwisely expressed expert's report.

I have spoken of engineers' reports as more or less formal reports prepared by independent engineers. However, a similar problem arises from interoffice reports and memoranda. In some ways, they are really more dangerous, because they are less likely to be brought to the attention of the lawyers and others working on the registration statement and may, therefore, turn up at some future date as an unexpected and unpleasant surprise. Such an interoffice report, if well written and convincing, which turned up later in the hands of a security holder with a clever lawyer, might cause much trouble, even though the reasons for not adopting the recommendations in the report had been overwhelming. Those reasons would probably never have been reduced to writing and might be extremely difficult to prove.

Questions in form A-2 under the headings Capital Securities and Description of Securities frequently require considerable work, but do not ordinarily present any difficulties. Summarizing the provisions of a complicated trust indenture may take time and trouble, but it does not take much else. Questions under the headings Underwriting, Proceeds and Their Application, Recent Sales of Securities by the Registrant, and Options usually present little difficulty. Those under the heading Management and Control are simple and require the disclosure of the compensation of directors and certain officers. Although objections to this are frequently made, I do not think that a change in this respect is likely.

MATERIAL CONTRACTS

Among the questions under the heading Miscellaneous is one that requires a description of all material contracts which are not made in the ordinary course of business. This question raises a great variety of problems, but, generally, the most difficult one is to determine whether or not a contract is made in the ordinary course of business. I do not know of any rule for determining this, and about the only guide is common sense. This offers a great opportunity for disagreement, and, as every one wants to play safe, the tendency has been to include too many contracts rather than too few in the answer to this question. Also there has been an unsound tendency to emphasize the amount involved in the contract, rather than the difficulty with which a substantially similar contract could be made with other persons if the contract was breached or terminated, or the damage that might arise from some unfavorable provision in the contract.

For example, if the issuing corporation has a contract under which it buys all its requirements of a certain raw material from one producer on terms that are substantially those generally current, if that raw material can readily be obtained from a large number of other producers, and if it can be terminated on reasonably short notice, it does not seem to me to be material, since, if it were terminated, such action would not seriously affect the business of the issuing corporation either adversely or favorably. If, however, the corporation has a long-term noncancellable contract to buy raw material at a price which, though favorable at the moment, may prove to be very unfavorable during part of the life of the contract, such a contract may be material. Also, if the corporation has a favorable contract to buy some essential raw material of which the supply is limited, such a contract may be material even though the dollar amount involved is small.

Another difficult problem under this question is convincing the executive officers of the issuing corporation that contracts which they wish to keep secret must be disclosed. I know of no remedy for this, except to avoid making such contracts. The fact that the officers of the corporation object to the disclosure of a contract, in itself, gives the underwriters and lawyers notice that the contract may be material.

Historical Financial Information is really a matter for the independent accountants and they should prepare and certify the answers to the questions under this heading. The financial statements must be all certified by independent accountants, although, in some cases, additional uncertified statements are filed. In the ordinary case, the statements required are a recent balance sheet and income statements for the last three years. Such statements are required not only of the issuing corporation itself but also of the issuing corporation and its subsidiaries consolidated. In some instances, separate statements of unconsolidated subsidiaries may be submitted. Every balance sheet and every income statement must be supported by a number of supplementary schedules. Financial statements filed with a registration statement appear to differ in at least one notable respect from those to which we were accustomed before the passage of the Securities Act. They are accompanied by a number of notes, which sometimes extend to several pages. These are due to the liability that has been imposed under the Securities Act, particularly on accountants. They as experts may become liable to any person who purchases the security; in other words, they are liable to a broad group of people who are not schooled in accounting and have no knowledge about the corporation and its business. In the past, accountants generally assumed that they were responsible only to the persons who employed them, namely the corporation and its officers and directors. All such persons could safely be presumed to have a considerable knowledge of the corporation and its financial affairs. While this certainly did not justify the accountants in certifying incorrect or incomplete financial statements, they nevertheless felt safe in assuming that the officers and directors of the corporation would read the statements in the light of usual accounting practice. Such an assumption is not safe with respect to the average investor and is the primary reason for including so much additional material as notes.

A tendency has arisen among corporation officers and also among many lawyers to assume that the entire responsibility for the financial statements rests on the independent accountants and that they alone will be responsible for any errors or omissions. This view is dangerous. Every officer, director, and underwriter may be liable for an untrue statement or omission in a report by an expert unless he can prove that he had no reasonable ground to believe and did not believe that the statement was untrue or that an omission had been made. This may be substantial protection to an underwriter but is not much protection to officers and directors who, as part of their duties, are presumed to be thoroughly familiar with the affairs of the corporation and have access to all its records. For example, it is the usual practice to describe the basis on which the property of the corporation is carried on its books. It is not inconceivable that the description prepared by the independent accountant may prove to be seriously inaccurate. Or the corporation may have a large contingent liability which is not shown on the books and of which the independent accountant has no knowledge. In both these cases, the certificate of the independent accountant probably will not furnish much protection to the officers and directors, particularly to those officers who are supposed to be in charge of the finances and accounting of the corporation.

Forms of reports required under the Securities Exchange Act are somewhat simpler. That known as form 10 is typical and is required when an application is made to list a security on an exchange. It is in addition to the listing application which is required by the exchange itself. The questions are similar to those in a registration statement under the Securities Act, but are fewer in number, and the financial statements are somewhat simpler, since an income statement for only one year is required. In addition, annual supplementary reports, which consist of new financial statements and such additional information as may be necessary to bring the original answers up to date, are required each year. A recent regulation requires a statement to be filed within ten days after the end of any month in which certain events take place, such as substantial change in the amount of outstanding securities, acquisition of a new subsidiary, the exercise or granting of options, and so on.

I have indicated that the liability in connection with statements filed under the Securities Exchange Act is not so severe as that in connection with a registration statement under the Securities Act. Nevertheless, the tendency is to treat the Exchange Act reports rather too lightly; they should be prepared with great care. Statements in such reports should not conflict in any material respect with those in a registration statement or the annual reports to stockholders. Such differences are most likely to appear in the financial statements and particularly in the notes. No substantial differences between the various financial statements should exist, and the accompanying notes should be substantially the same. Certainly variations will occur, but they should be avoided unless they can be soundly justified. Technical requirements in the financial statements on the forms used under these Acts in some cases are immaterial and, therefore, can be omitted from the annual report, and some notes may be appropriate to a comparative income statement for three years which are not necessary with an income statement for a single year. Many people will regard this advice as technical and excessively cautious, but I think that they have failed to visualize the difficulty of explaining, for example, the omission of a note that was included in a registration statement from an annual supplementary report, which was filed within a few weeks of filing the statement.

RESULTS OBTAINED

To give anything but the most general impressions as to the effectiveness of this legislation is impossible. With respect to actual fraud in the sale of securities, the Commission has been able to accomplish a good deal and this may prove to be one of its most valuable contributions. The Commission has a large organization assigned to this branch of its work, and its activities in this field are constantly increasing.

In theory, at least, the main purpose of the Securities Act was to compel full disclosure and so protect investors from buying new issues that might subsequently turn out to be unsound. Undoubtedly, it has and will prevent some losses but it may not prove as effective in this respect as people generally believe. Actually, investors will not examine the information that is furnished, and it would not do them much good if they did. Certainly, statistical organizations may make use of it, and, as a result, the price at which a new issue is offered may be affected, but I doubt if the necessity of disclosing additional facts has prevented many new issues. The chief cause of the losses of 1929 was not insufficient information but lack of sound financial judgment, and you cannot manufacture judgment by legislation. Investment, by its very nature, involves losses as well as profits and income, and to change that economic law is neither possible nor healthy. Of course it is possible to redistribute the profits and losses and the liability provisions of the Securities Act may bring about some such redistribution.

Estimating the effect that the margin regulations and the provisions directed against manipulation may have had on speculation is extremely difficult. Certainly the volume of trading is materially reduced, and this is probably due, in part, to a reduction in the number of small speculators and, in part, to the fact that pool operations have been substantially prevented. Opinion may differ to some extent as to the importance of these results. Personally, I have no doubt that they are important and healthy, and ultimately, I think, legislation will require that all lending on securities be done by the banks and not by the brokers, although the transition will undoubtedly be difficult for the members of the stock exchanges.

Indirectly, both Acts are having certain desirable effects on corporate finance. A change in the approach to accounting problems and an improvement in the method of presenting financial statements can be seen already. Accountants are insisting on a consistent application of sound accounting principles and on the full disclosure of any variations. As a result, the attention of corporate officers and directors has been focused on accounting problems. A good example is depreciation, on which the Commission has properly placed considerable emphasis, particularly by requiring a statement of the depreciation policy to accompany every balance sheet. As a result, I think, more consideration is being given to working out sound long-term depreciation policies which will not require frequent changing and which are based on the estimated actual requirements of the property. On occasions in the past, requirements of the balance sheet and income statement had considerable influence on depreciation policies.

For the present at least, the tendency will be to pass additional legislation supplementing these Acts and increasing the powers of the Commission. Ultimately, some reaction may take place, but this will not be in the near future nor will it go very far. Additional legislation will inevitably be proposed and probably passed dealing with protective committees, and such legislation will contain provisions regulating the duties of trustees. Further efforts by the Commission to increase its control of over-the-counter dealers and transactions may be expected, although this presents some constitutional difficulties and many administrative problems. Some effort may be made to enact a federal incorporation law, with inducements to encourage incorporation under it, instead of under state laws. In many respects, a federal incorporation law would be extremely desirable, if properly drafted and reasonably and intelligently administered. Such a law would offer an almost unlimited opportunity to extend governmental regulation of business. While some increase of governmental regulation may be inevitable and desirable, it is such a difficult problem that it should be approached with care and caution. Since this paper was delivered the Lea and the Barkley Bills have been introduced in Congress. The former gives the Commission broad powers concerning solicitation of proxies, deposits, and assents in connection with judicial reorganizations and also with mergers, consolidations, and most voluntary readjustments. The latter requires the qualification of trust indentures with the Commission and, among other things, gives that body broad powers to require the inclusion of certain provisions in trust indentures.

Without any change in the present legislation, the Commission is in a position substantially to increase its activities, and this will take place more or less gradually. A number of provisions in the Exchange Act do not become operative unless and until the Commission adopts regulations to carry them out. Work on such regulations is reported to be in progress

in the Commission and presumably regulations will be produced in the near future. There is undoubtedly strong support in the Commission in favor of the adoption of a system of uniform accounting and something will eventually be done in this connection. I think this will be unfortunate, for I believe a system of uniform accounting will tend to produce low rather than high standards of accounting, and this view is shared by many leading accountants.

Another method by which the Commission might increase its influence in corporate affairs is through the proxy section of the Exchange Act. Present regulations are simple, but the power given in the Act, although rather limited, would permit more extensive regulations. Furthermore, the suggestion has been made that the Commission might hold itself out as ready and willing to receive proxies from the stockholders of any corporation, and, as the holder of such proxies, attend and take an active participation in the conduct of the meeting. If the Commission announced that it was prepared to act in this way, it would, no doubt, receive proxies from stockholders for every meeting of practically every corporation of substantial size. Such a policy would undoubtedly impose extraordinary responsibilities on the Commission, and possibly the fear of such responsibilities will effectively prevent any such action.

COOPERATION WITH COMMISSION

What should the management of a corporation do to equip itself to comply with this legislation and to minimize its burdens? Perhaps most important of all is the mental approach. Whether we like it or not, this legislation has come to stay, and we will have to live with it. I do not agree with many of the policies and rulings of the Commission, and I am frequently irritated by what I consider unnecessary red tape. But I always assume that the Commission is trying its best to do its duty and to be fair. If I think some question in one of the forms is foolish or immaterial or ambiguous, I nevertheless do my best to furnish the information I believe the Commission was seeking to obtain, even though it may not be called for by a literal reading of the question. I believe my attitude is sound, and I urge you to adopt it. At any rate, I have always found the Commission cooperative and fair.

Bear in mind that all the statements which must be filed, particularly form A-2, require time to prepare and that the time allowed is rarely sufficient. Issuing new securities overnight is no longer possible, and plans for new financing should be made many months ahead of time. In the case of a corporation with widely scattered foreign subsidiaries, a year may be needed to prepare the first registration statement properly. Of course, the first will be much harder than the subsequent statements, but, in any event, a long time is necessary to do a thorough job. If vexatious litigation and possible liability are to be avoided, every statement and every report filed under either the Securities or the Securities Exchange Act should be properly prepared. Every effort should be made to make them all as accurate and complete as possible. This will involve time and trouble and frequently expense but will, in the end, prove to be the wise policy.

Certainly, the preparation of the various statements and reports is much simpler if the corporation has a simple capital structure. That is not a sufficient reason for changing the capital structure, but a simple capital structure possesses many advantages, and this is one more. By a simple capital structure, I mean not only not too many classes of securities, but also simple provisions, and, in general, a capital structure which is based on sound principles of finance rather than on taking advantage of every liberal provision contained in the corporation law.

With respect to accounting, I recommend employing the best possible independent accountants, consulting them continuously, and following their advice. Before engaging in any important transaction which will affect the financial position of the corporation, consider with the accountants how it should be handled in accordance with good accounting practice, what the book entries should be, and how they will affect the balance sheet and income statement. Do not follow the more usual policy of completing the transaction first, making rather haphazard book entries to cover it, and then begin thinking about it after the books are closed for the year. Many of the notes which now accompany most balance sheets and income statements are due to unsound or unthought-out accounting practices. With forethought, many future accounting problems can be avoided.

Remember that everything that you do may become public. The greatest complaints are usually made about the disclosure of salaries and other forms of compensation and of material contracts. Whether you like it or not, publicity as to salaries has come to stay, and I doubt if such publicity has done anyone much harm. Disclosure of material contracts probably is damaging in certain instances, but I am fairly certain that it is ordinarily far less damaging than is generally claimed. Disclosure of the terms of a contract means little or nothing except to competitors. To them, the disclosures will rarely be a great surprise.

Every corporation should see that at least one officer makes himself an expert and keeps himself currently informed with respect to these Acts and the rules and regulations. Relying entirely on lawyers is not safe or fair to the lawyers. Lawyers these days are forced to know a little about everything and are sometimes assumed to have a thorough knowledge of business and accounting. They are trained to give the appearance of having such knowledge, but it does not always go very deep. To have an executive who is not a lawyer thoroughly familiar with these matters is important, if the preparation of the various statements is to be done efficiently and with reasonable effort and expense.

In addition, however, every executive should make it his duty to become, and to keep himself, sufficiently familiar with this legislation and with the rules and regulations of the Commission so that he will have a sound understanding of the general underlying principles.

Courtesy the Midvale Co.

VESSELS *Under* EXTERNAL PRESSURE

Theoretical and Empirical Equations Represented in Rules for the Construction of Unfired Pressure Vessels Subjected to External Pressure

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NEW "Rules for Construction of Unfired Pressure Vessels Under External Pressure" were prepared by the A.S.M.E. Special Research Committee on the Strength of Vessels Under External Pressure at the request of the Boiler Code Committee. These rules were first published[1] in 1934 and have since been incorporated in the A.S.M.E. Code for Unfired Pressure Vessels (A.S.M.E. Boiler Construction Code, Section VIII), 1934 edition, Pars. U-120 to U-138, inclusive.

In order that the rules might be given in the simplest possible form, the theoretical and empirical formulas involved were represented by curves. These formulas are presented and discussed in this paper.

INTRODUCTION

The rules apply to vessels of the types considered in Fig. U-20, reproduced here from the code. Such vessels are essentially thin cylindrical shells. A thin cylindrical shell under external pressure is in certain respects analogous to a column. As is well known, the behavior of a column or strut in compression is quite different from the behavior of a rod in tension. A member in tension will continue to carry load until after the yield point of the material is reached, whereas, the same member in compression might buckle and become incapable of carrying increased load at stresses far below the yield point. Moreover, the presence of initial irregularities in a tension member is of little importance while the presence of the same irregularities in a compression member might greatly reduce its strength.

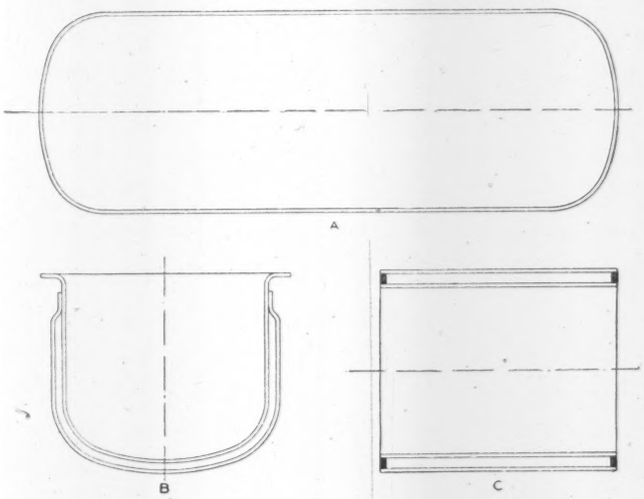


FIG. U-20 THREE TYPICAL FORMS OF UNFIRED CYLINDRICAL VESSELS SUBJECTED TO EXTERNAL PRESSURE

In much the same manner, the behavior of a vessel under external pressure differs from the behavior of one under internal pressure. The shell of a vessel under internal pressure will continue to carry load until after the yield point of the material is reached, and its strength is not greatly impaired by the presence of initial dents or irregularities. The shell of a vessel under external pressure on the other hand might buckle at very low stresses, and its strength might be greatly reduced by the presence of initial irregularities or departures from true circular form.

Columns may be divided into two classes: Those which become unstable and buckle at stresses well below the yield point, and those which fail at stresses approaching the yield point of the material. Pressure vessels can be classified in the same way. Relatively long, thin-walled pressure vessels become unstable and collapse at stresses well below the yield point while relatively short, thick-walled pressure vessels collapse at stresses approaching the yield point of the material. It is the possibility of unstable collapse that is the distinguishing feature of structures under compression.

FORMULAS FOR THE COLLAPSE OF VESSELS UNDER EXTERNAL PRESSURE

The strength of a vessel under external pressure depends upon its three dimensions of length L, diameter D, and thickness t, and the mechanical properties of the material. Technical literature contains a large number of formulas—many are listed in (1 to 5)[2]—for computing the collapsing pressure of such vessels. Some formulas are comparatively simple, others are extremely complicated; no one of the proposed formulas is applicable to all ranges of the dimensions D, L, and t.

Before discussing these formulas, it is well to consider first in a general way the relationship between the length of a pressure vessel and its strength. The heads of a very long vessel are too far apart to exert an appreciable influence on the central portions of the shell; the collapsing pressure of the vessel is thus independent of its length and depends upon only its thickness-diameter, t/D, ratio. The heads of a vessel shorter than a certain "critical length," by tending to maintain the original circular form of the shell, have considerable influence upon its

[1] "Proposed Rules for the Construction of Unfired Pressure Vessels Subjected to External Pressure," MECHANICAL ENGINEERING, vol. 56, 1934, pp. 245–249.
Contributed by the A.S.M.E. Boiler Code Committee.

[2] Numbers in parentheses refer to the Bibliography at the end of the article.

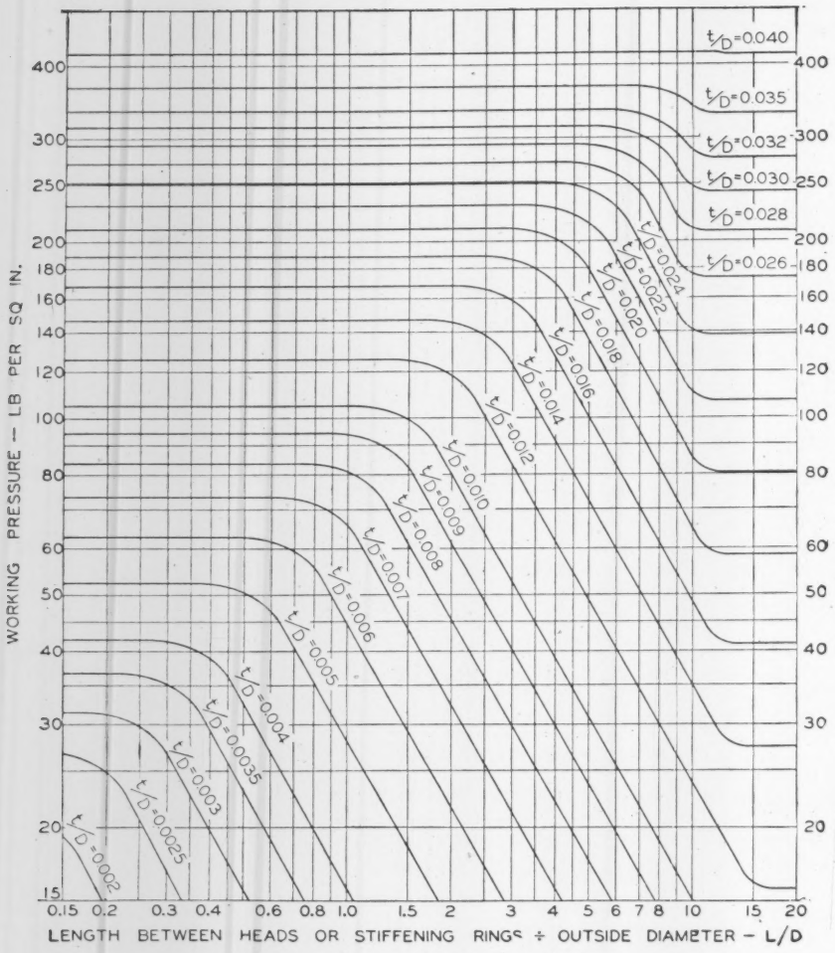


FIG. U-21 CHART FOR DETERMINING SHELL THICKNESS OF UNFIRED CYLINDRICAL VESSELS SUBJECTED TO EXTERNAL PRESSURE WHEN CONSTRUCTED OF STEEL COMPLYING WITH SPECIFICATIONS S-1, S-2, S-4, S-17, S-18, S-25, S-26, S-27

strength. Thus, for vessels of ordinary dimensions, other factors remaining constant, the shorter the vessel the greater its strength; i.e., the collapsing pressure depends not only upon the t/D ratio but upon the L/D ratio as well. The heads of a very short vessel, however, are so close together that they prevent collapse of the shell until it is stressed to the yield point, and the collapsing pressure of the vessel is again practically independent of the length and depends only upon the t/D ratio. If bulkheads or stiffening rings of adequate rigidity are used, they are equivalent to heads in determining the effective length L of a pressure vessel.

It is thus seen that vessels of different lengths have entirely different characteristics; consequently, the strengths of the vessels must be computed from different formulas. Before any progress could be made in formulating a pressure-vessel code from the many published formulas it was necessary to classify them. The formulas can be divided into three general types: (*a*) stress, or yield formulas for short pressure vessels; (*b*) instability formulas, containing both L/D and t/D, for vessels of intermediate length; and (*c*) instability formulas, containing t/D only, for long pressure vessels.

The use of the formulas in the actual design of pressure vessels is ordinarily no simple matter. Usually, the designer is given the length and diameter, or volume, of a proposed pressure vessel and the maximum external pressure to be applied; he is required to determine the necessary shell thickness. Since pressure-vessel formulas give the collapsing pressure in terms of given dimensions, the determination of the shell thickness is often an indirect, trial-and-error procedure, various values of thickness being substituted until the desired collapsing pressure is obtained. Separate calculations must be made with both stress and instability formulas to determine which is applicable, i.e., to determine what is the probable type of failure. Usually, a considerable amount of computation is necessary in applying existing formulas to the design of a pressure vessel.

To eliminate this tedious procedure, the Special Research Committee considered it desirable to examine the various theoretical and empirical formulas, to determine which was best for each range, and then to construct a series of curves representing the chosen formulas. Accordingly, one formula of each type was selected from each group, and these were represented by a series of curves, which are shown in Fig. U-21.

DISCUSSION OF THE CHART, FIG. U-21

Fig. U-21 permits the direct determination of the required t/D ratio for a given L/D ratio and working pressure. Moreover, it avoids the necessity of calculations to determine which formula is applicable, for the curves of the chart were constructed in such a manner that no formula is represented in a region where it does not apply. Thus, with the use of the

chart, the selection of the correct formula is automatically taken care of. In the construction of the chart, a factor of safety of 5 and the following values for the physical properties of steel were assumed:

S_y = yield point, 27,500 lb per sq in.
S_p = proportional limit, 22,500 lb per sq in.
E = elastic modulus, 29×10^6 lb per sq in.
μ = poisson's ratio, 0.3

The t/D curves in the upper left-hand corner of the chart are horizontal. This region applies to the short vessels previously mentioned where failure occurs when stresses in the shell approach the yield point. The formula used to determine collapsing pressure in this region is

$$p = 5P = \frac{2S_y(t/D)}{1.05} \quad \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

where P is working pressure, p is collapsing pressure, and S_y is the yield point of the material, all three quantities being expressed in the same units when the thickness t is expressed in the same units as the diameter[3] D. Formula [1] is merely the simple hoop-stress formula with a 5 per cent reduction factor. This factor is based on both theoretical considerations and experience.

A thorough stress analysis of a thin-walled pressure vessel, reinforced by stiffening rings and subjected to uniform radial and axial pressure, was made by von Sanden (2). His final results are expressed in Equations [92] and [92*a*],[4] which will be found in the Appendix. The former gives the pressure at which the longitudinal stress, i.e., bending plus axial stress, at the stiffener reaches the yield point; the latter gives the pressure at which the tangential stress midway between stiffeners reaches the yield point. These formulas involve the dimensions of the stiffener as well as the dimensions of the vessel itself.

The correction factor in formula [1] was fixed at 5 per cent because, for stiffening rings of ordinary dimensions, the tangential stress indicated by Equation [92*a*] is about 5 per cent greater than the simple hoop stress. The theoretical difference between the two reaches about 10 per cent for the case of bulkheads or stiffeners of infinite rigidity, but this extreme value is not justified by experience and was not incorporated in formula [1].

Equation [92] indicates that the longitudinal stress in the shell at the edge of a heavy stiffening ring may exceed the simple hoop stress by considerably more than the 5 per cent assumed in formula [1]. It was considered unnecessary to make allowance for this in the code, however, for two reasons. First, the longitudinal stress at the stiffener, the local deformation of which is ignored by theory, is probably not as high as Equation [92] predicts, and, secondly, it is not longitudinal stress, but tangential stress that is determinative in the collapse of a thin-walled pressure vessel. High longitudinal stress at the stiffener edge may cause local yielding of the shell but not its collapse. This is evidenced by tests on vessels with heavy stiffening rings or bulkheads. For example, in Fig. 3 of the paper, "Strength of Thin Cylindrical Shells Under External Pressure" (3), the ridges which clearly outline the positions of the stiffening rings indicate local yielding of the shell in large regions where no bulging occurred.

Altogether, with the use of stiffening rings permitted by the chart, Fig. U-25, formula [1] with its 5 per cent reduction factor is entirely adequate.

The central portion of the chart, where the t/D curves are

[3] In all theoretical formulas, D is the diameter to the neutral surface. However, in the Code, Par. U-122, D is taken as outside diameter. The difference is usually negligible, and the use of outside diameter is on the side of safety.

[4] As originally published, this equation contained an error. See Appendix.

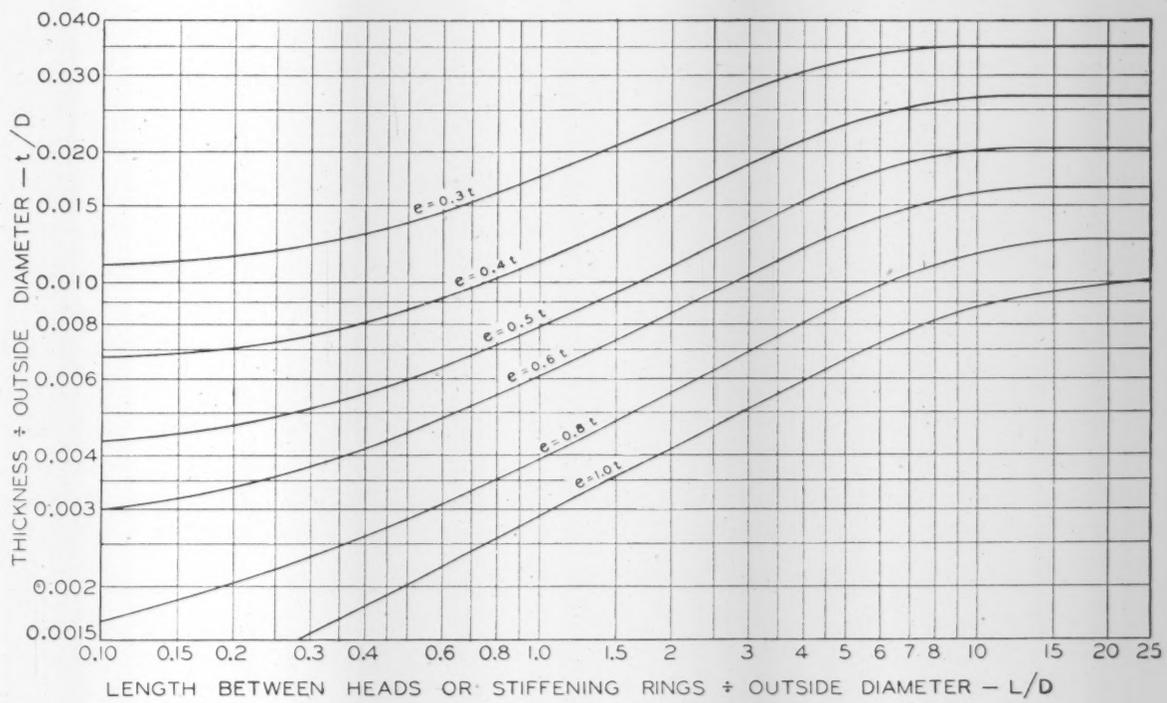


FIG. U-23 ALLOWABLE DIFFERENCE IN MAXIMUM AND MINIMUM DIAMETERS FOR UNFIRED CYLINDRICAL VESSELS SUBJECTED TO EXTERNAL PRESSURE

(Maximum diameter — minimum diameter = e.)

inclined, applies to vessels that fail by instability of the shell at stresses below the yield stress. The formula used to determine the collapsing pressure in this region is

$$p = 5P = \frac{2.60E(t/D)^{5/2}}{(L/D) - 0.45(t/D)^{\frac{1}{2}}} \quad \ldots\ldots [2]$$

When the diameter D, length L, and thickness t are all expressed in the same units, the working pressure P and the collapsing pressure p are expressed in the same units as the elastic modulus E. Theoretical instability formulas appear to be in fair agreement with one another in the range in which they apply. The simple formula [2] is a close approximation to probably the best instability formula for pressure vessels of intermediate length. A discussion of formula [2] and its derivation are given in a previous paper (1).

On the right-hand side of the chart, the t/D curves are again horizontal. This area applies to the long vessels previously mentioned where the heads are too far apart to offer additional strength to the central portion of the vessel. The formula used to determine the collapsing pressure in this region is

$$p = 5P = \frac{1}{1.27}\frac{2E}{1-\mu^2}(t/D)^3 = 50.2 \times 10^6(t/D)^3 \ldots [3a]$$

This is the generally accepted Bresse-Bryan (6, 7) theoretical formula for geometrically perfect, long, thin tubes under external pressure with a 27 per cent reduction factor. This factor makes formula [3a] identical with the empirical equation of Stewart (4) and Carman (5) derived from tests on long commercial tubes and pipes. This formula has long been incorporated in the A.S.M.E. Boiler Construction Code, and it has been found satisfactory in practice.

Formula [3a] is for long thin tubes which fail by instability at stresses well below the yield point. Naturally, there is an upper limit of t/D, at which the tube becomes a thick tube or pipe which fails at stresses that approach the yield point and for which formula [3a] ceases to apply. Stewart (4) set this limit at $t/D = 0.023$ and proposed the empirical linear relation

$$p = 5P = 86{,}670(t/D) - 1386 \quad \ldots\ldots [3b]$$

for the collapsing pressure of long tubes with t/D greater than 0.023. There is a small region on Fig. U-21, where it was necessary to use formula [3b] instead of formula [3a].

The intersection of the curves expressed by formulas [2] and [3a] or [3b] indicates the "critical length" (8, 9), i.e., the length at which the strengthening influence of the heads is no longer felt.

Substitution for S_y in formula [1] of the assumed proportional limit determines the limit of applicability of formula [2]. At stresses between the proportional limit and the yield point, the modulus of the material decreases rapidly with increasing stress. Hence, formula [2] can be used only when E is replaced by the proper reduced modulus (10, 11). This refinement was not used, however, for the material specifications of the A.S.M.E. Boiler Construction Code specify only ultimate tensile strength, yield point, and elongation for the steels for which Fig. U-21 is applicable, thus allowing considerable variation in the stress-strain curves. Consequently, the transition curves shown in Fig. U-21 were drawn in by judgment. They correspond to practically straight lines in a rectangular coordinate system.

REQUIRED MOMENT OF INERTIA OF STIFFENING RINGS

Stiffening rings are frequently desirable. The reduction in the effective length of a vessel by the use of suitable stiffening rings will often greatly increase the strength of the vessel without correspondingly increasing the weight or cost.

The curves, represented in Fig. U-25, for determining the required moment of inertia of stiffening rings are based on the formula

$$I_s = \frac{0.035}{E} D^4 \frac{L}{D} p = 6 \times 10^{-9} D^3 LP \quad \ldots\ldots [4]$$

where D is the outside diameter of the vessel, in.; I_s is the required moment of inertia of the cross section of the stiffening ring about the centroidal axis parallel to the axis of the vessel, in.^{4}; L is the center-to-center distance between stiffening rings, in.; and P is the working pressure, lb per sq in.

This formula is derived from Lévy's formula (12, 17) for the buckling of a circular ring under uniform external pressure

$$q = \frac{3EI}{r^3} \quad \ldots\ldots [A]$$

where q is the load per unit circumferential length of the ring and r is the radius to the neutral axis of the ring.

It is considered desirable in pressure-vessel design, as an insurance against loss of life and property, to make stiffening rings strong enough to resist collapse, even after the shell has collapsed by bulging between them. Accordingly, stiffeners are designed for a collapsing strength at least 10 per cent higher than the strength of the shell (2, 3). Hence, assuming that the shell offers no support after buckling but transfers all its load to the stiffeners, the design collapsing load of the stiffener should be

$$q = 1.1pL \quad \ldots\ldots [B]$$

Although the support of the shell is ignored in computing the load on the stiffener, it is found by experience that a portion of the shell acts as part of the stiffening ring and contributes to its effective moment of inertia. Just how much of the shell is effective is not definitely established, but a strip equal in width to the flange width is a conservative allowance (2, 3). Hence, in applying Equation [A], I_c, the moment of inertia of the compound section consisting of the stiffener and a portion of the shell, should be used.

The use of I_c, however, instead of I_s, the moment of inertia of the stiffening ring alone, is very cumbersome, since the choice of a suitable stiffening ring is indirect. A promising section must be assumed and the moment of inertia of the compound section then be computed and tried in Equation [A].

To avoid the labor involved, a conservative ratio of I_c/I_s that could be used for all stiffeners was sought. An examination of a great many calculations made on various pressure vessels in actual service using different types of stiffeners revealed that I_c/I_s varied from 1.3 to 1.7 with the majority of values between 1.4 and 1.5. $I_c/I_s = 1.3$ was adopted as a conservative value for the rolled sections in common use and a safe value for any type of stiffener. By substituting 1.3 I_s for I, 1.1 pL or 5.5 PL for q, and $D/2$ for r in Equation [A], formula [4] is obtained.

PERMISSIBLE OUT-OF-ROUNDNESS

For the purpose of this discussion, out-of-roundness or eccentricity in a pressure vessel is defined as the difference between the maximum and minimum radii in any plane normal to the axis of the vessel measured within the region of one bulge or one-half lobe length. Since such variations from true circular form may reduce the strength of a pressure vessel, the committee felt that some upper limit for out-of-roundness

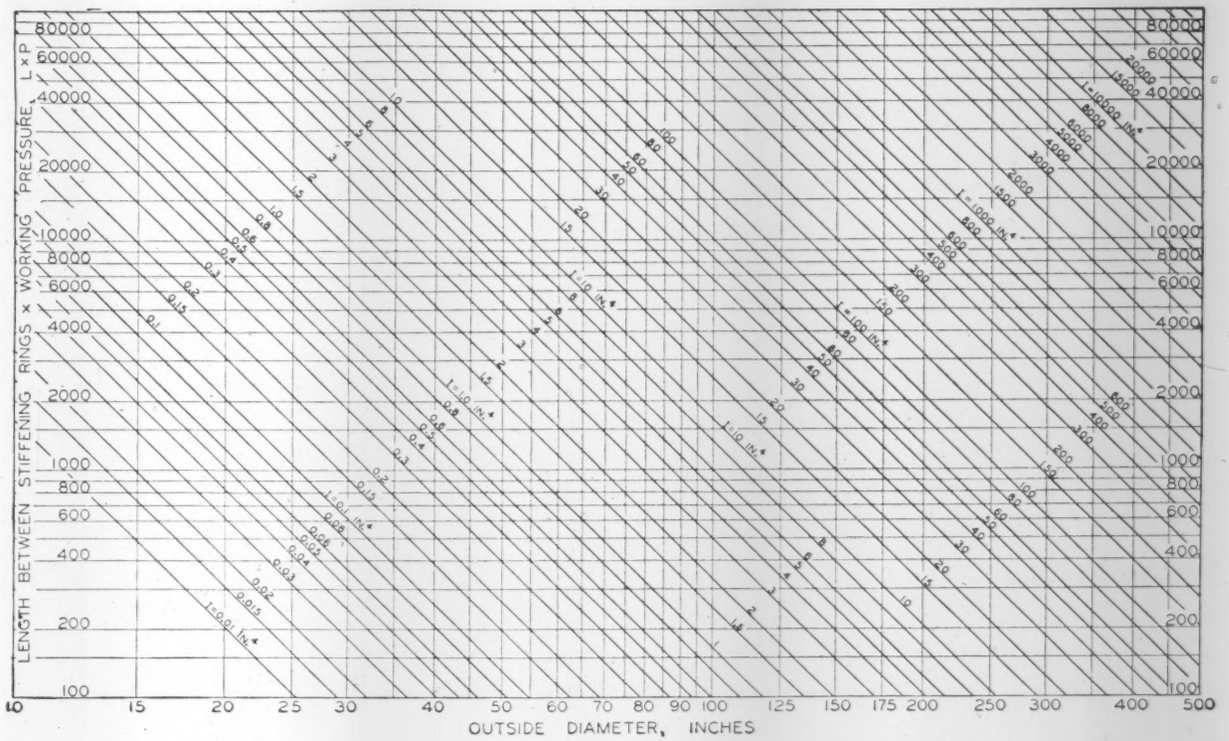


FIG. U-25 REQUIRED MOMENT OF INERTIA OF STIFFENING RINGS FOR UNFIRED CYLINDRICAL VESSELS SUBJECTED TO EXTERNAL PRESSURE

should be established, by which vessels could be judged as satisfactory or unsatisfactory. The curves given in Fig. U-23 represent an attempt to meet this requirement. They are based on the empirical formula

$$e/t = \frac{1.8}{n(100t/D)} + 0.015n \quad \ldots\ldots [5]$$

where e is the permissible out-of-roundness i.e., the maximum out-of-roundness or eccentricity allowed, and n is the number of lobes or waves in a complete circumferential belt of the shell at collapse.

Formula [5], though empirical, has a somewhat rational basis. In establishing this formula, an analogy was drawn between a pressure vessel and a column by considering the shell of the pressure vessel to be made up of a series of columns, one half lobe-length long, extending end-to-end circumferentially around the vessel. It is easily shown (1) that the pressure-vessel analog of the slenderness ratio of column theory is

$$1/r \propto \text{a constant}/[n(t/D)] \quad \ldots\ldots [C]$$

The eccentricity of a column corresponds to the out-of-roundness of a pressure vessel, and the commonly used eccentricity ratio e/r of column theory has the pressure vessel analog

$$e/r \propto \text{a constant } (e/t) \quad \ldots\ldots [D]$$

since the radius of gyration of the shell $r = t/\sqrt{12}$.

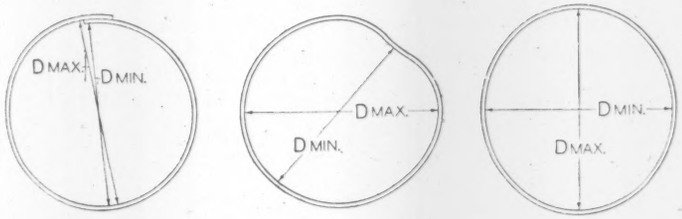


FIG. U-24 EXAMPLES OF VARIATION FROM CIRCULAR FORM IN UNFIRED CYLINDRICAL VESSELS SUBJECTED TO EXTERNAL PRESSURE

It is now possible to use column data to predict the effect of eccentricity on the collapsing strength of pressure vessels. The work of Westergaard and Osgood (13) shows that the same eccentricity will weaken a long column less than a short one of the same cross section. Bleich (14) agrees with this. Jezek (15, 16) should also be consulted in this connection.

If the permissible eccentricity e is taken as that eccentricity which will reduce the strength of a column or pressure vessel by a given percentage, it follows that for columns

$$e/r \propto l/r \quad \ldots\ldots [E]$$

and for pressure vessels

$$e/t = \frac{\text{const}}{n(100t/D)} \quad \ldots\ldots [6]$$

The general form of Equation [6] is substantiated to some extent by experiments with pressure vessels. Since n decreases with increasing L/D, as shown in Fig. 1 of "Collapse by Instability of Thin Cylindrical Shells Under External Pressure" (1), Equation [6] indicates that for a constant t/D, e/t increases as L/D increases. In agreement with this, it is found experimentally that a given eccentricity has less effect on the collapsing pressure of a long tube than of a short one with the same thickness and diameter. Equation [6] indicates further that for a constant L/D, e/t decreases with increasing t/D. This does not conflict with the meager experimental evidence available.

Equation [6] can be conveniently represented on a logarithmic $L/D - t/D$ coordinate system, as in Fig. U-23. The curves representing constant values of e/t are approximately straight and parallel with positive slopes. These curves appear satisfactory for vessels of intermediate length, but

the following considerations show that they should be flattened somewhat in the extreme regions for both long and short vessels.

For short columns, the allowable eccentricity no longer decreases with decreasing l/r but actually increases slightly (13). This is equivalent to saying that in pressure vessels the allowable out-of-roundness decreases with decreasing length until a certain limit is reached and then increases slightly for further decrease in length. This increase in allowable eccentricity can be ignored, since it is small and in the direction of safety. However, the e/t curves should at least flatten out and continue parallel to the L/D axis for small values of L/D.

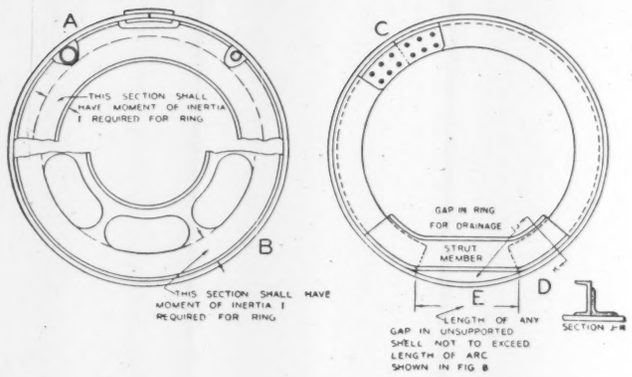
On the other extreme, when the length of the vessel is increased, a critical length is reached, beyond which further increase in length does not influence the collapsing pressure. At this critical length, it is reasonable to assume that further increase in length does not justify further increase in permissible eccentricity. Hence, the e/t curves should flatten and continue parallel to the L/D axis as L/D is increased beyond the critical length.

Thus, the general shape of the required e/t curves is determined. They should be practically horizontal in the extreme regions of both very short and very long vessels, and the slope of the curve connecting these regions should be positive.

There remains then to properly modify the basic Equation [6] and so find a suitable combination of the variables which will give curves of the type desired. It was found that the equation

$$e/t = \frac{a}{n(100\ t/D)} + bn \qquad [7]$$

approaches these requirements. Values of the constants must now be obtained which will give reasonable and safe values of permissible out-of-roundness throughout the region of t/D and L/D covered by the rules.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D
E
THIS SECTION SHALL HAVE MOMENT OF INERTIA I REQUIRED FOR RING
THIS SECTION SHALL HAVE MOMENT OF INERTIA I REQUIRED FOR RING
GAP IN RING FOR DRAINAGE
STRUT MEMBER
LENGTH OF ANY GAP IN UNSUPPORTED SHELL NOT TO EXCEED LENGTH OF ARC SHOWN IN FIG 8
SECTION J-K

FIG. U-26 VARIOUS ARRANGEMENTS OF STIFFENING RINGS FOR UNFIRED CYLINDRICAL VESSELS SUBJECTED TO EXTERNAL PRESSURE

The constants were evaluated from the following values:

t/D	L/D	e/t	n
0.003	0.15	0.6	15
0.003	6	2.0	3
0.01	1	0.5	5
0.03	1 to 10	0.3	2

The first three values of e/t were chosen by judgment for a region which has been fairly well covered by tests (1, 3). It is quite certain that none of these eccentricities will reduce the collapsing strength of carefully constructed pressure vessels by as much as 20 per cent (1).

The last value of e/t was chosen because it represents an out-of-roundness of about 1 per cent of the diameter for the thickest pressure vessel included in these rules. Since the A.S.M.E. Code for Unfired Pressure Vessels (Par. U-79) now requires that this value be not exceeded, the requirement evidently can be readily met by manufacturers. The experiments of Stewart (4) indicate that such an eccentricity will not

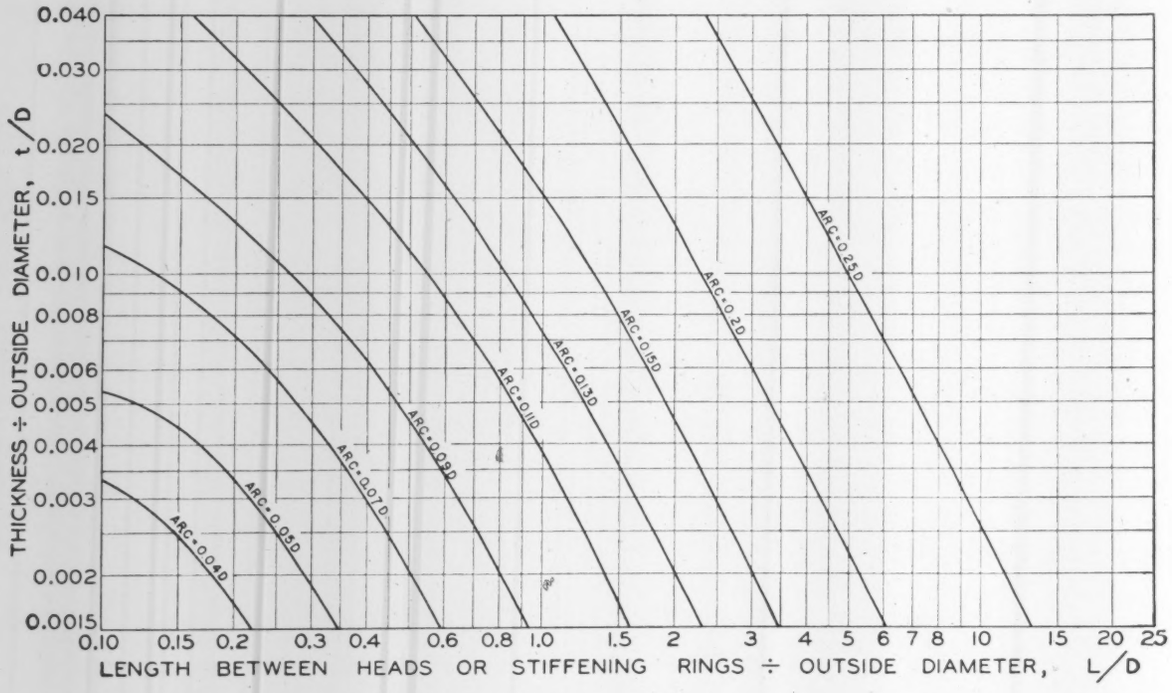

FIG. U-27 MAXIMUM ARC OF SHELL LEFT UNSUPPORTED BECAUSE OF GAP IN STIFFENING RING OF UNFIRED CYLINDRICAL VESSELS SUBJECTED TO EXTERNAL PRESSURE

reduce the collapsing pressure by more than 20 per cent below that predicted by formulas [3*a*] and [3*b*]. The necessity of extreme caution in fixing out-of-roundness requirements for pressure vessels, and especially thick ones, is indicated in the theoretical work of Timoshenko (17). He shows that even small initial eccentricities may weaken a vessel considerably.

Evaluating the constants of Equation [7] by the method of least squares leads to formula [5], which has been plotted in Fig. U-23.

It is to be noted that the value of e/t appearing in formula [5] is permitted in the length of one bulge or one half lobe length. For simplicity, out-of-roundness is defined in Par. U-125 as the difference between the maximum and minimum diameters, not radii, measured in the entire circumference, not one-half lobe length, as illustrated in Fig. U-24. Since it is possible for a vessel to meet a certain out-of-roundness limitation in all half-lobe lengths and yet fail to meet that limitation for the entire circumference, taking measurements in the entire circumference instead of in the length of one bulge may, in some instances, make the out-of-roundness requirements slightly more severe.

Out-of-roundness measurements have seldom been made in the past, and the opinions of manufacturers vary greatly as to what tolerances can be met without unwarranted increase in cost. However, some actual measurements made on pressure vessels now in service, together with manufacturers' opinions as to what further tolerance would have been considered justifiable, have been collected by the Special Research Committee. It was found that in practically every case the eccentricities allowed by Fig. U-23 exceeded those actually measured. Moreover, in most cases, the values allowed were well above the values estimated by the manufacturers as satisfactory shop practice. It appears, therefore, that the tolerances allowed by formula [5] or Fig. U-23 are now being readily met by certain manufacturers. More liberal allowances should be permitted only as the result of extensive measurements on full-scale pressure vessels which have proved satisfactory in service.

At present, there are not sufficient data available to make provision in the code for vessels which do not meet out-of-roundness requirements, nor does the code state how much extra thickness of plating is necessary to compensate for excessive out-of-roundness. In fact, an apparent inconsistency arises in Fig. U-23 in this connection. If a manufacturer uses a shell thickness greater than actually required by Fig. U-21, the code seems to penalize him in that Fig. U-23 gives a smaller allowable out-of-roundness for that increased thickness. The reason for the anomaly is that the decreased allowable out-of-roundness is not only for the increased t/D but also for the resulting increased P. Naturally, then, when a manufacturer uses thicker plating than required, he is privileged to use the out-of-roundness allowance for the required and not the actual t/D.

GAPS IN STIFFENING RINGS

In pressure-vessel design, it is frequently necessary or convenient to leave gaps in that portion of a stiffening ring supporting the shell, as shown at A and E in Fig. U-26. Accordingly, an attempt was made to establish a safe criterion for the permissible arc length of these gaps.

For this purpose, it is convenient to consider a long plate supported at the edges, subjected to a uniform compressive end load in its plane. There is a striking similarity between such a plate and the belt of shell in a pressure vessel between circumferential stiffening rings because of the uniform tangential (hoop) stress throughout the belt. Both plate and pressure vessel fail in a series of characteristic bulges, to both the same column analogy applies, and for both the analogous column length is one bulge.

Timoshenko (17) shows that the critical buckling load of a long plate with simply supported edges is four times the Euler load for the analogous column. If a gap is made in the supports, the plate in this region becomes a real column of length equal to the gap. If the gap is one bulge in length, the buckling strength of this "exposed column" is only one fourth of the buckling strength of the plate. If the gap is decreased to one half bulge in length, the strength of the exposed column is increased fourfold according to Euler's theorem and hence becomes about equal to the plate strength. Hence, it may be concluded that a gap in the supports of a plate one-half bulge or less in length will not materially decrease the strength.

Now a gap in the stiffening rings of a pressure vessel is equivalent to a gap in the supports of a plate. It may be concluded, therefore, that a gap in a stiffening ring of a pressure vessel, one-half bulge or one fourth lobe or less in length, will not materially decrease the strength of the shell.

Fig. U-27 requires that the maximum unsupported arc of the shell shall not exceed one fourth lobe length. The lobe lengths were obtained from von Mises' Equation [6] (18) which is represented graphically in a previous paper (1).

ACKNOWLEDGMENT

The author wishes to point out that this paper represents the combined work of all members of the A.S.M.E. Special Research Committee on the Strength of Vessels Under External Pressure. Acknowledgment is due also to Charles Trilling of the U. S. Experimental Model Basin staff for valuable assistance in its preparation.

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APPENDIX

Von Sanden-Günther formulas (2) for the collapse of vessels under external pressure are given in Equations [92] and [92*a*].

$$p_v = \frac{2\frac{t}{D}s_y}{\frac{1}{2} + \sqrt{\frac{3}{1-\mu^2}}K\frac{1-\frac{1}{2}\mu-B}{1+\beta}}$$

$$= \frac{2\frac{t}{D}s_y}{\frac{1}{2} + 1.81\,K\frac{0.85-B}{1+\beta}} \qquad [92]$$

$$p_v = \frac{2\frac{t}{D}s_y}{1 + H\frac{1-\frac{1}{2}\mu-B}{1+\beta}}$$

$$= \frac{2\frac{t}{D}s_y}{1 + H\frac{0.85-B}{1+\beta}} \qquad [92a][a]$$

where

A = cross-sectional area of frame
b = flange width of frame in contact with shell
D = diameter to the neutral axis of the shell
L = effective length of vessel
p_v = external collapsing pressure of shell

[a] This equation as originally published (2) contained an error. The coefficients of the transcendental terms in the numerator of the function H were interchanged, and the sign connecting these terms was minus instead of plus.

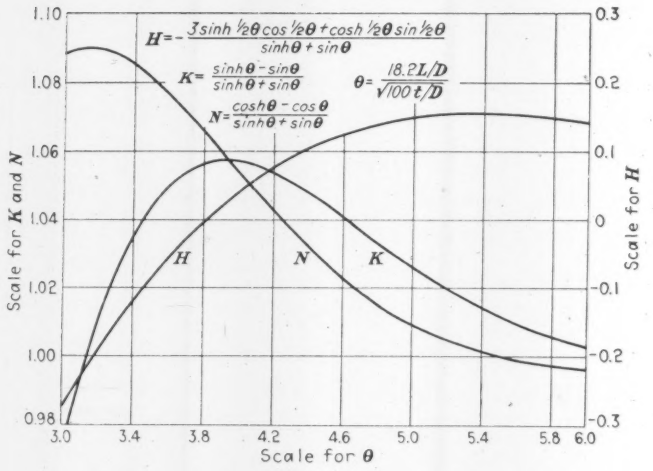

FIG. 1 AUXILIARY FUNCTIONS, K, N, AND H, FOR USE IN THE VON SANDEN-GÜNTHER EQUATIONS [92] AND [92*a*]

s_y = yield point of the material
t = thickness of shell
μ = Poisson's ratio, assumed = 0.3

$$B = bt/(A + bt)$$

$$\theta = 10\sqrt[4]{12(1-\mu^2)}\,\frac{L/D}{\sqrt{100t/D}} = \frac{18.2L/D}{\sqrt{100t/D}}$$

$$\beta = 2\frac{L}{b}\frac{NB}{\theta} = \frac{11N}{\sqrt{100t/D}}\,\frac{t^2}{A+bt}$$

$$N = (\cosh\theta - \cos\theta)/(\sinh\theta + \sin\theta)$$

$$K = (\sinh\theta - \sin\theta)/(\sinh\theta + \sin\theta)$$

$$H = -2\,\frac{\left[1 + \sqrt{\frac{3\mu^2}{1-\mu^2}}\right]\sinh\frac{\theta}{2}\cos\frac{\theta}{2} + \left[1 - \sqrt{\frac{3\mu^2}{1-\mu^2}}\right]\cosh\frac{\theta}{2}\sin\frac{\theta}{2}}{\sinh\theta + \sin\theta}$$

$$= -\frac{3\sinh\frac{\theta}{2}\cos\frac{\theta}{2} + \cosh\frac{\theta}{2}\sin\frac{\theta}{2}}{\sinh\theta + \sin\theta} \quad \text{(approximately)}$$

Galloway, N. Y.

Security in

ENGINEERING EMPLOYMENT

Fourth Series of Results of the Survey of the Engineering Profession Conducted by the U. S. Bureau of Labor Statistics

THREE summary reports based on analyses made by the United States Bureau of Labor Statistics of returns from 52,589 professional engineers have already appeared.[1] The present article, which deals with security of employment in the engineering profession, as related to means of securing employment, civil-service status, the employment contract, provision for retirement on pension, and patent privileges enjoyed by engineers, is based on the fourth report.[2]

The study on which the reports are based was undertaken in May, 1935, at the request of the American Engineering Council. A questionnaire, mailed to 173,151 engineers, directed the engineer replying to it to indicate how he obtained his position and to answer certain questions regarding the other points covered by the present report. The data here summarized were supplied by 35,559 engineers who reported the field of engineering engaged in and who had an engineering job on Dec. 31, 1934. Because the complete summary report is available, only the following portions are quoted in this article:

MEANS USED TO OBTAIN EMPLOYMENT

The data furnished by engineers concerning the medium through which they obtained employment demonstrate that for the engineering profession as a whole, placement was not the function of any particular organization. The vast majority of professional engineers obtained their jobs through personal contacts and recommendations. This was the means used to find the position held in 1934 by no less than 68.4 per cent of the 35,559 engineers who also reported the field of engineering activity in which they were engaged. Personal contacts and recommendations, together with civil service, accounted for 74.2 per cent of the mechanical and industrial engineers. For each of the remaining professional classes, these two mediums covered approximately four fifths of their respective totals, ranging from 78.4 per cent of the chemical and ceramic to 81.5 per cent of the civil engineers. Mechanical and industrial engineers reported relatively higher percentages of jobs obtained through an engineering society, a private employment agency, and newspapers.

Only 2.4 per cent of all engineers reported that they obtained their positions through an engineering society. Some 3.7 and 2.7 per cent, respectively, of the mechanical and industrial, and mining and metallurgical engineers were so classified. For the three remaining professional classes, the percentages ranged from 1.4 to 1.9. Despite the fact that so few engineers reported an engineering society as their employment medium, it must be recognized that such societies are an important factor in obtaining employment for professional engineers. It is obvious that through their members there must inevitably be a pooling of information on employment prospects, both locally and nationally. Furthermore, the officials of the various societies are kept in close touch with local and national employment conditions as a result of their meetings and conventions; but such appointments as are made would depend rather upon personal contacts and recommendations than upon contacts made through the society's employment service. The fact, therefore, that only 2.4 per cent of all engineers reported the engineering society as their medium of employment must be interpreted in the light of these conditions.

The securing of employment through newspapers and technical journals was reported by 1.6 and 1.0 per cent, respectively, of all engineers making returns.

Private employment agencies were used by only 1.6 per cent of all engineers reported. Public employment agencies embraced approximately the same proportion, 1.5 per cent.

Despite the fact that, in all, 11,177 of the engineers reporting were in the employ of public authorities in December, 1934, only 45.0 per cent of them reported as being under civil service. The proportion of all engineers with civil-service status was 48.4 per cent in the case of positions under the federal government and for employment with state and county, and municipal governments, 36.1 and 45.6 per cent, respectively.

THE EMPLOYMENT CONTRACT

For the engineering profession as a whole, the data clearly evidence a lack of economic security in terms of a written contract which would secure employment over a substantial period of time. In all, only 3169, or 8.9 per cent, of the 35,559 engineers who reported employment in an engineering field[3] were covered by a written contract. Of these, some 0.8 per cent had a contract for less than 1 year, 3.5 per cent a contract for between 1 and 2 years, and only 0.9 per cent for 2 years or more. Engineers who did not report as to period of contract formed 3.7 per cent of the whole. No less than 91.1 per cent either answered "No" or did not furnish specific information.

Comparison of the positive returns on employment contract from all engineers in the three broad fields of engineering activity, private engineering, public engineering, and personal

[1] "Education of the Engineer," MECHANICAL ENGINEERING, August, 1936, pp. 505–509. Also "Educational Qualifications in the Engineering Profession," *Monthly Labor Review*, June, 1936, pp. 1528–1542; also reprinted as Bureau of Labor Statistics Serial No. R. 400.

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[2] "Security of Employment in the Engineering Profession," prepared by Andrew Fraser, Jr., Division of Wages, Hours, and Working Conditions, Bureau of Labor Statistics, *Monthly Labor Review*, May, 1937.

[3] Throughout the whole of this discussion, only engineering employment is considered. Consequently, no cognizance has been taken of the economic security of engineers engaged in nonengineering employment.

service, shows that use of the contract was most common in personal service—primarily education. For engineers under contract in the personal-service field the most common contract period (reported by 25.6 per cent of the 2778 engineers so engaged) was from 1 to 2 years. Some 4.0 per cent were under contract for periods of 2 years or longer. Although the corresponding percentages for public engineering were much lower than for personal service, they were higher than for private engineering. For employment contracts under 1 year, however, private exceeded public engineering (1.0 per cent, as against 0.5 per cent). Of all reporting engineers engaged in public engineering, 2.0 per cent had contracts for 1 and under 2 years, and 1.1 per cent for periods of 2 years and over. The corresponding percentages for private engineering were 1.4 and 0.5 per cent.

For the separate fields of activity under private engineering, relatively the largest proportion of engineers under contract in their jobs occurred in manufacturing, with 408, or 3.8 per cent, of the 10,888 reporting as so engaged. In the construction and extractive industries 3.0 and 2.0 per cent, respectively, had written contracts. The smallest proportions under contract were reported by engineers employed by public utilities or engaged in transportation (1.1 and 0.9 per cent, respectively).

The data also confirm the previous finding that engineers engaged in teaching are relatively more secure with regard to employment than other members of the engineering profession: 33.8 per cent of their number reported written contracts for periods of from 1 to 2 years. Sales employments, next in order, had under contract for a similar period only 3.9 per cent of their 1513 reporting engineers, and general administration and management only 2.3 per cent. Each of the other functional classes had less than 2.0 per cent. Even for the contract periods of 2 years and over, teaching covered 4.8 per cent of the total reported for this functional class. The next highest percentage, namely, 1.5, was reported for general administration and management. In no one of the remaining employments did the percentage of engineers with written contracts for 2 years and over exceed 0.8 per cent.

Thus, with regard to fields of activity or the functional classes within them, the engineering profession cannot be said to have any substantial security of employment provided through a written contract for a period of time. On the other hand, professional engineers are not generally restricted with regard to the seeking of employment similar to that in which they may be engaged. This is evidenced by a consideration of the data furnished by professional engineers concerning their separation-contract status.

Only 1.4 per cent of all the reporting engineers stated that they were under a contract for a definite period of time during which they bound themselves not to seek similar employment. This included 0.8 per cent whose separation contracts were for less than 1 year, 0.2 per cent for a period of from 1 to 2 years, and 0.4 per cent for 2 years and over. Clearly, restrictions upon professional engineers with regard to new employment were few.

PROVISION FOR RETIREMENT ON PENSION

As of December, 1934, almost one third (10,641) of the 35,559 professional engineers reporting who had engineering jobs at that time stated that they had pension privileges. Of this number, 6684, or 18.8 per cent were covered by contributory pension schemes, and 3957, or 11.1 per cent, by noncontributory schemes. Some 57.8 per cent were in employments for which no pension provision had been made. About 12.3 per cent did not furnish information.

Of the engineers in pensionable positions, the smallest relative proportion, 26.2 per cent, was engaged in private engineering. By contrast, 37.4 per cent of the engineers engaged in public engineering and 29.0 per cent of those in personal service had pension privileges. For public engineering and personal service the contributory scheme predominated. On the other hand, of the engineers engaged in private engineering, the largest proportion was covered by noncontributory systems. However, within the private-engineering group marked differences were shown; the same was true of the three categories of public engineering.

The largest number of professional engineers covered by a pension plan were those in the employ of the federal government. Out of a total employment of 4649 engineers reporting, 43.2 per cent were under a contributory and only 5.3 per cent under a noncontributory plan. The corresponding proportions in positions with state and county, and municipal governments were very much less—26.9 and 1.3 per cent, respectively. For municipal-government employment the figures were 29.9 and 2.4 per cent.

Among the remaining fields of activity, public utilities and transportation reported the next highest proportions (after federal employment) as having pension privileges. Public utilities and transportation used the noncontributory scheme; this type of plan covered 37.2 per cent in utilities and 33.1 per cent in transportation; contributory systems covered only 8.2 and 9.6 per cent, respectively, of those reporting. For the three remaining pursuits shown under private engineering, the largest number of engineers with pension privileges did not exceed 25.7 per cent, and in all cases contributory schemes predominated.

From the preceding discussion of the pension privileges it is quite evident that the kind of employment has a marked effect upon the question of the installation of a pension scheme. In no type of engineering employment was a majority of the reporting engineers protected by such a plan.

PATENT PRIVILEGES IN THE ENGINEERING PROFESSION

Information as to patent privileges was furnished by 61.6 per cent of the 35,559 reporting engineers with engineering jobs at the end of 1934.

Of all engineers covered, 31.7 per cent reported retention of the patent rights for all inventions made either in the course of their work or in fields not directly related to their work. Among the nine separate fields of employment this was true of the largest group in each case, except in manufacturing where the highest proportion (30.1 per cent) reported that they had no rights to patents relating to their work, but did retain their rights to those not directly related to their work. This latter combination ranked second in importance and included 16.9 per cent of the 35,559 engineers. The third group in importance (including 4575, or 12.9 per cent) was that reporting complete restriction on both aspects of patent privileges. Only 42 engineers, less than 0.1 per cent of the total, reported that they retained the rights to inventions connected with their duties but not to those not so connected.

It would seem that, comparatively, there is only slight restriction on the retention of patent rights among professional engineers, although its extent varies in the different fields of employment. Thus, relatively the greatest restriction was placed upon engineers engaged in manufacturing, 19.0 per cent of whom reported complete restriction, 30.1 per cent the right to patent inventions not directly related to their work but not to those made in the course of their work, and only 23.1 per cent no restrictions. In the extractive industries the limitations, while less severe than in manufacturing, were nevertheless greater than in any of the other branches of private engi-

neering. Complete restriction was reported by 15.6 per cent of the engineers in the extractive industries, by 11.8 per cent of those in construction, and by 11.4 per cent of those in transportation; the smallest proportion, 8.9 per cent, was reported for engineers in the employ of public utilities.

It has already been noted that in manufacturing some 30.1 per cent of the engineers so engaged had the right to patent inventions not directly related to their work, but not to those made in the course of their work. This partial restriction was very much less for the remaining fields of activity in private engineering. In the case of extractive industries, only 18.6 per cent so reported, in transportation 17.3 per cent, and in public utilities 16.0 per cent. Partial restriction affected only 8.6 per cent of the engineers engaged in construction. These same four fields of activity did, however, report larger proportions as being unrestricted with regard to patent privileges. These ranged from 32.6 for extractive industries to 42.4 per cent for public utilities. It will be recalled that only 23.1 per cent of the engineers in manufacturing so reported.

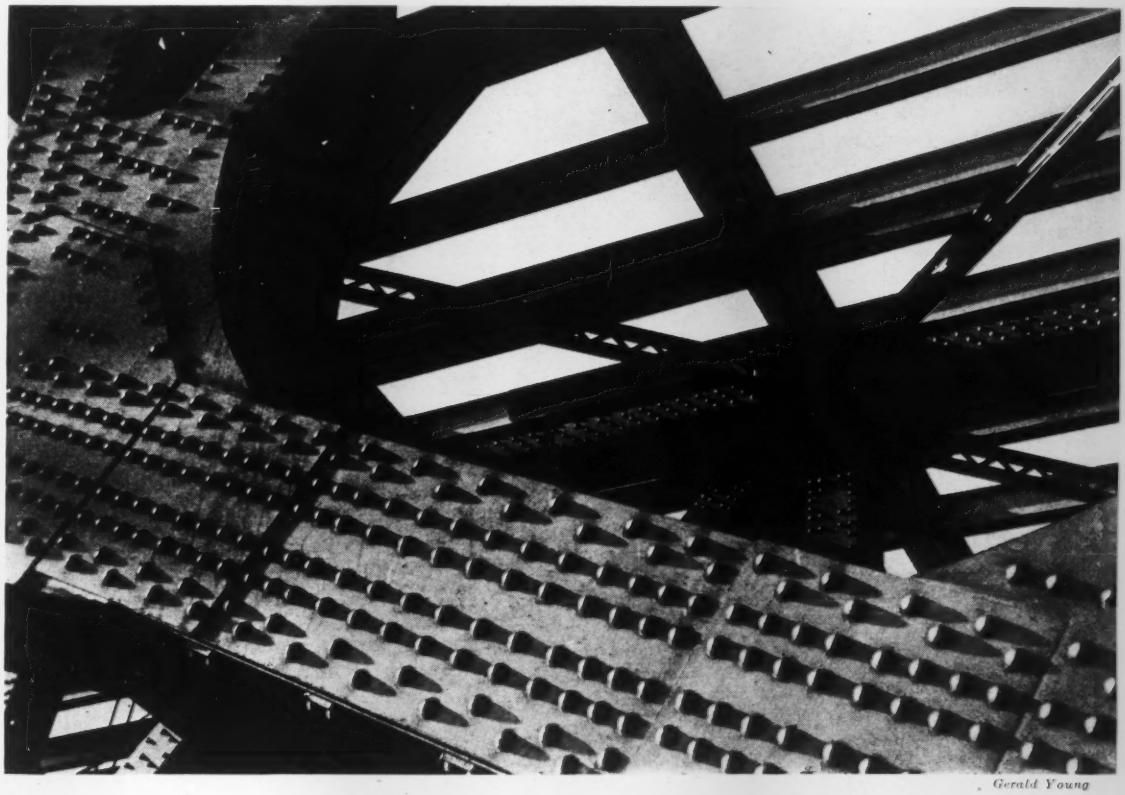
In the three classes of public engineering, there was a marked divergence in the restrictions placed upon patent privileges. This was greatest for engineers in the employ of the federal government, 12.2 per cent of whom had no patent privileges whatsoever, whereas in state and county, and municipal governments only some 9.0 per cent were under complete restriction. Partial restriction affected 12.5 per cent of the federal-government engineers, but only about 5.5 per cent of those in the other two public employments. The greatest divergence occurred for those engineers who reported they had the right to patents made in the course of their work and also to those not directly related to their work. This group included only 21.7 per cent of federal-government engineers, whereas for state and county, and municipal governments, the percentages reported were, respectively, 35.8 and 36.7.

Relative to all other fields of activity, the least restrictions were found in personal service, where 50.4 per cent reported unrestricted patent rights, 9.7 per cent partial restriction, and only 5.3 per cent no patent privileges. This freedom from restriction in the retention of patent rights for engineers in the personal-service group was due to the preponderance of teachers in this group.

Engineers engaged in teaching were under the least restriction as to the retention of patent rights, and engineers in design and research were under the greatest restriction. Of the 9050 engineers classified as working in design and research, only 23.5 per cent had the right both to patents made in the course of their work and those not directly related to their work. As many as 55.3 per cent of the engineers engaged in the teaching of engineering subjects so reported. For the remaining five lines of work, the proportions with full rights to patents ranged from 29.9 per cent in sales to 33.6 per cent in general administration and management.

Relatively, the largest proportion of engineers who were partially restricted in regard to patent rights (26.6 per cent) was reported for design and research. Even in the case of sales, some 20.5 per cent were classified under this "No—Yes" combination. By contrast, only 18.1 per cent of the engineers engaged in operation and 16.0 per cent in general administration and management were restricted only as to patents relating to their work. The corresponding proportions in construction, consulting, and teaching were very much less, ranging from 8.7 in construction to 9.7 in teaching.

The largest relative percentage completely restricted was 19.4—for the engineers engaged in sales—with design and research following next in order (15.8 per cent). From this point the proportion ranged downward to 13.4 per cent in operation, 12.1 per cent in general administration and management, 11.5 per cent in consulting, and 10.8 per cent in construction. The lowest percentage under complete restriction, namely 4.4, was noted in teaching.



Gerald Young

FACING *the* TAX PROBLEM

By DONALD S. TUCKER

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

TAXATION involves complex problems. Description of such problems in clear, simple language is an achievement of which Professor Shoup[1] and his associates may be justly proud. Public expenditures and taxation also touch closely upon current political issues. For this reason it is difficult to avoid bias in either the wording or arrangement of a report, yet the recent volume published by the Twentieth Century Fund seems to have accomplished this also. The findings of the research staff and of the committee cover many aspects of local, state, and federal taxation. The authors are interested primarily in improving our tax system, but their findings as to fact are of especial interest here.

"On an average every person in the United States pays $100 a year in taxes. . . Another $15 or $20 a person would be needed if borrowing were to be ended and expenditures were to continue undiminished. . . More than one fifth of what statisticians call national income is used to pay taxes—and the tax money, when it is paid out in government expenditures, in turn accounts for more than one fifth of the national income. The fraction would be close to one fourth if borrowing were to be replaced by an increase in taxes."

One hundred dollars a person means that in 1937 approximately $12,500,000,000 will be collected in taxes. Of this amount state governments receive about 2.5 billions, local governments about 4.5 billions, and the federal government about 5.5 billions. One hundred and seventy-five thousand taxing jurisdictions, chiefly units of local government, receive this income. Two taxes, however, contribute more than half of the revenue—property taxes (4.5 billions) and income taxes (2.6 billions). Three other taxes contribute more than half a billion dollars annually. These three of the second rank are the levies on gasoline (850 millions), liquors (800 millions), and tobacco (550 millions). In the third rank come sales taxes, pay-roll taxes, death taxes, customs duties, motor-vehicle taxes, and gift taxes. In the fourth rank come numerous other forms of taxation which, though individually less important, collectively contribute more than a billion dollars to the revenues of federal and state governments.

Federal revenues have changed their character greatly within the last 25 years. In 1913 customs duties contributed nearly half (48 per cent) of the federal revenue. During the World War customs revenue diminished and other revenues increased so that in 1918 tariff duties contributed only 5 per cent of the federal income. After the war their percentage increased to 18 per cent in 1923; but since then the customs revenue has diminished erratically. In 1937 the tariff is expected to contribute only 7 per cent of the federal revenues.

In 1913 internal taxes (52 per cent of the federal total) consisted chiefly of liquor taxes (35 per cent). Revenues from this source dwindled, then substantially disappeared; after the repeal of prohibition they rose again, but constitute for this year only 11 per cent of the federal revenue. Because liquor taxes are used also by state governments, the taxes on liquor contribute twice as much revenue to our governments as do the customs duties, nevertheless liquor taxes no longer belong in the first rank as sources of government revenue.

State governments as well as federal now draw their revenues from highly diversified sources. As recently as 1902 general property taxes contributed more than half of the state tax revenue. Two changes have occurred since that time. New sources of state revenue have been found, and states have reduced their demands upon the general property tax. In 1937 only 7 per cent of state tax revenues were drawn from the property tax and many of the more important states have abandoned this tax as a source of state revenue.

In contrast with these tendencies in state and federal taxation, local governments have developed no new sources of taxation. They rely chiefly on the general property tax and the general property tax has thus become substantially segregated for the use of county governments and their more local subdivisions. Since revenues from property taxes diminished greatly during the depression, three tendencies appeared in local government: These units curtailed their services sharply, they became recipients of state subventions, and in some instances they surrendered to state governments the administration of activities formerly controlled locally. Local self-government has diminished in part because our life is now less localized but in part because of fiscal necessities.

"Federal expenditures increased gradually from 1925 to 1930. The total increase ... was less than 10 per cent. Thereafter they rose rapidly with depression demands, nearly doubling in the five years 1930 to 1935 when the total ... was $7,272,000,000." In 1936 federal expenditures were 8.88 billions. For the years 1937–1940 they are estimated. Because many services cannot be abandoned quickly, the minimum estimate for federal expenditures in 1940 exceeds 6.5 billion dollars.

State expenditures were less influenced by war and depression than were those of the federal government, but state expenditures have grown more rapidly than federal. During the period 1910–1930 federal expenditures increased fourfold, state expenditures were multiplied by seven. State expenditures then remained at about the same level (2.2 billion) during the period 1930–1935, but promise now to resume their former rate of rapid growth. Growth of state expenses in the next few years may well offset all possible economies by the federal government.

Local expenditures also show plainly the popular demand for increased government service. In 1910 local expenses were less than 1.6 billion. Twenty years later they exceeded 7.2 billions. Reduced revenues caused a drastic cut to 5.2 billion in 1933 and thus helped to compel the increase of expense by other levels of government. Many of the burdens surrendered by local units 1930–1935 will undoubtedly remain in the new hands, but growth of population and increasing demands for service promise by 1940 to carry local expenses once more above their 1930 level (7.2 billions).

Government expenses for 1940 may therefore assume figures somewhat like the following: Local 7 billions, federal 6 billions, and state 5 billions. This estimate should of course

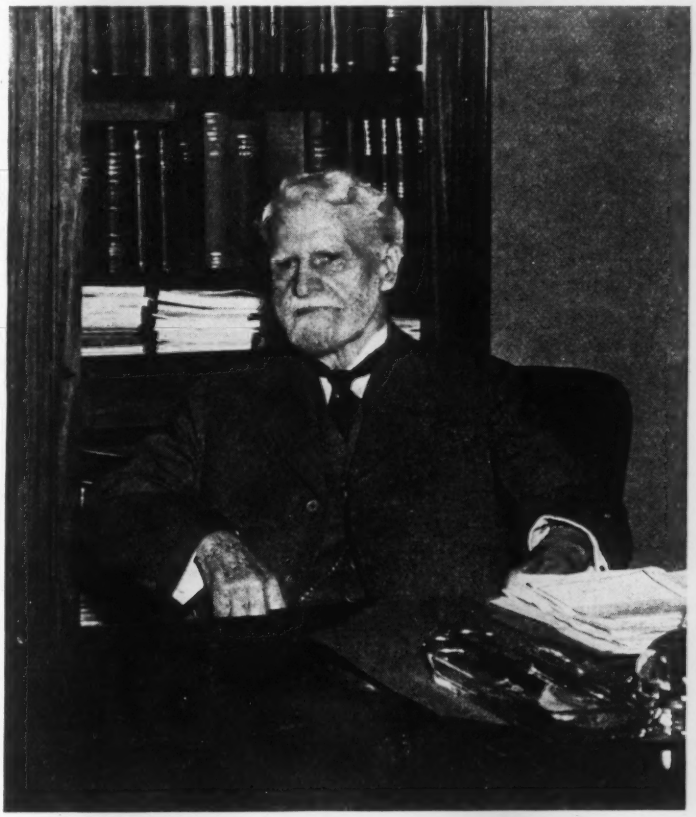
(*Continued on page 614*)

[1] "Facing the Tax Problem," Twentieth Century Fund, Inc., New York, 1937.

One of a series of reviews of current economic literature affecting engineering prepared by members of the department of economics and social science, Massachusetts Institute of Technology, at the request of the Management Division of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

AMBROSE SWASEY, 1847–1937

AT A time when the quiet and enduring virtues of New England character seem to be temporarily in eclipse, the death of Ambrose Swasey comes to testify to their greatness. In Ambrose Swasey they flowered and fructified and demonstrated how men of humble origin but good heredity may be influenced by their environment to make the most of their talents and opportunities. The ferment of New England at the height of its spiritual and intellectual development was strong within him. His Exeter background, the creative atmosphere of the New England workshop, and a long life maturing in the transplanted New England of the Western Reserve mercifully spared him from the frustration of decadence which Santayana has recently characterized in "The Last Puritan." Neither Beacon Hill nor State Street robbed him of the ennobling experiences of honest craftsmanship in the mechanic arts or of participation in the mighty drama of the emergence of the industrial culture that applied science has now made typical of our present civilization. If the intellectual and religious problems that raised havoc with so many of his contemporaries troubled him, there is no indication of it to be found in his life and character, for he seems to have been able to face their dilemmas and paradoxes in the creative and evolutionary spirit that pervaded his philosophy and his career. If, in his ninety first year, he returned to spend his last days in the simple environment of his birthplace, it was from no nostalgia born of a belief that the good old days were the best and that he longed to have them back, for he had maintained as recently as his 90th birthday that this was not so. "Time modifies all this," he is reported to have said, "People will get used to it and go right on living."



PORTRAIT OF AMBROSE SWASEY
Taken on May 3, 1937

The facts of Ambrose Swasey's career have been often told. Born in Exeter, N. H., on Dec. 19, 1846, the youngest child of Nathaniel and Abigail Peavey Swasey, his formal schooling was confined to a few years spent at the old Plains school house of his native town. He was endowed with a sound body and clear mind, and a simplicity and sincerity of character inherited from one of New England's earliest families that had earned the respect of Exeter for the part played in its history.

His life's work began with an apprenticeship at the Exeter Machine Works, where native talent in the use of mind, eye, and hand developed into a rare skill in precision craftsmanship, later capitalized in the building of machine tools and astronomical instruments. Here it was that Mr. Swasey became the lifelong friend of Worcester Reed Warner, with whom he was subsequently to establish the famous firm of Warner and Swasey. With Warner he went, in 1869, to Hartford, Conn., to work in the shops of Pratt and Whitney. It was during this period in his career that Mr. Swasey devoted much time and thought to the precision manufacture of gears, being in charge of that department of the company's business, and here he developed the epicycloidal gear-cutting machine.

But Warner and Swasey were confident of the great future for the machine tool industry and in 1880 formed a partnership and opened a business of their own in Chicago. Events proved that the sources of skilled mechanics and opportunities for successful manufacturing were brighter in Cleveland, and hence the business was removed to that city in 1881, where the great works bearing that name still thrives. Material successes required continuous enlargement of the enterprise until the partners, in 1906, when the plant was enlarged to three times its former size, decided that further expansion should be resisted. They wanted, Mr. Swasey explained, some time "to travel, to look about us, to pass some time with our friends, and to enjoy the good things of life." This they did, with that rare sense of balance and obligation to themselves and their associates and friends that brought richness to their lives and broadened the scope of their influences.

This is no place to give in detail the history of a successful machine-tool building enterprise that has become famous the world over, or to enumerate the specific contributions to technology made by Mr. Swasey. But there existed in the enterprise and in Mr. Swasey's passion for perfection that *sine qua non* essential to the great instruments of astronomical science. Warner and Swasey became famous as the builders of mountings for telescopes, and the list of their endeavors to place instruments of the highest quality at the disposal of astronomers is a list of many of the world's great observatories. Ever larger and more important instruments came from their shops, and for many of these their old friend, John A. Brashear, kindred of their simplicity and greatness, provided the lenses. "We have never made money out of telescopes," Mr. Swasey once said with characteristic insight, "but the money we have put into that end of our business has brought us invaluable returns in the form of contacts which have helped in the production and sale of turret lathes, to which we look for profit." This far-sighted idealism, so typical of the New England roots from which it

sprang, has been accepted by the great industries of today as a working philosophy, the basis of sound and sure advance.

It was natural that a man of Ambrose Swasey's genius and temperament should join The American Society of Mechanical Engineers in the first year of its history. Had he been close to New York, he would, undoubtedly, have been among its founders. And it was natural also that he should find in the Society an opportunity to develop his warm appreciation of personal friendship with men of his own interests and ideals. As years passed and the Society and Mr. Swasey grew, his qualities of inspirational leadership and engineering ability forced him into a position of unusual prominence among engineers. This Society and others never tired of doing him honor, and he never tired of helping them directly through his benefactions and services, and indirectly by the light shed on them by his fame and the esteem in which the world held him. In 1904 he served the Society as its president; in 1916 the Society made him an honorary member; in 1924 the Founder Societies awarded him their highest honor, the John Fritz Medal; in 1933 he became A.S.M.E. Medalist; in 1936, at the time of his ninetieth birthday, with Herbert Hoover present, the Society made him the only other recipient of the Hoover Gold Medal. The list of his other honors and awards is too long for mention, but it includes the Legion of Honor of the French government and honorary degrees from many colleges and universities.

Ambrose Swasey's list of honors is rivaled in length and brilliance by the list of his benefactions. In a funeral oration delivered at the First Baptist Church, Exeter, N. H., "his mother's church," as he often called it, which one of his ancestors, Elizabeth Swasey, had helped to found in 1800, its minister, the Reverend Howard P. Weatherbee, told of Mr. Swasey's first experience in giving. "He, with his brother," said Mr. Weatherbee, "went out into the woods and chopped a couple of cords of wood and hauled it to the Baptist parsonage where Rev. Noah Hooper lived. It was this Noah Hooper who baptized him in 1864 and who later officiated in his wedding ceremony. But this giving of the wood to the church was his first experience in giving."

Throughout his life Ambrose Swasey continued to give to his church, to educational institutions, to the poor, to science, and to engineering. Many of his benefactions are unknown, but among those that the world knows stands out the gift of $750,000 with which he set up the Engineering Foundation in 1914. His interest in this project has placed engineers of all societies forever in his debt. Toward the purchase of the site for the building to house the National Academy of Sciences and the National Research Council in Washington he made generous contribution. He was the donor, with Warner, of the Warner and Swasey observatory of the Case School of Applied Science; he gave an observatory to Denison University; he endowed the chair of physics at the Case School of Applied Science, occupied by his friend Dr. Dayton C. Miller; he established a library for the Colgate-Rochester Divinity School at Rochester, N. Y.; he erected a building for the Canton Christian College (now Lignan University), and a science building for the University of Nanking. Mr. Swasey, it is said, was largely responsible for the German government's return to the Chinese of the famous astronomical instruments taken from the Great Wall to Potsdam during the Boxer rebellion. To the little church at Exeter he donated two memorial windows and an organ which he never lived to hear played. For his native town he converted the land along the western bank of the Swampscott River into the Swasey Parkway and in Exeter Square he erected a pavilion.

Mere catchpenny concern with business affairs combined with rare talent and unusual astuteness may build up a great industrial enterprise and win a more than usual amount of earthly riches, but the qualities of character Mr. Swasey possessed endeared him to his friends for himself alone, and the circle of these friends was an ever-widening one which included much more than that of a successful manufacturer could. His city revered him for his civic interests; he had an honored standing in banking circles. Patron of education, his name was known throughout the land and his face and influence were familiar in several institutions. Among scientists he moved as friend, benefactor, and colleague. He rarely missed meetings of the American Philosophical Society and the National Academy of Sciences (two months before his death he had attended a meeting in Washington of the latter) and at these meetings, as in engineering gatherings, he was greeted with friendly affection by young and old. His business associates gave up years ago urging him to spare his strength; he preferred activity to senility which never overtook him. He died, as no doubt he had hoped he would die, with his long career unblighted by the extensive period of illness that saddens family and associates with the spectacle of a broken mind or body, and at the place of his birth and burial. He returned from whence he came.

Friends of Mr. Swasey who best sensed the fine simplicity, sincerity, and humility of his character knew that he valued highly his relationship to the Baptist Church. Whatever success he may have achieved in worldly affairs and whatever satisfaction this may have meant to him were enriched by this spiritual tie to the best traditions of his family and early training. But however spiritual and idealistic this tie may have been, it bound him also to the practical affairs of his church and creed. He served the Baptist Education Society of New York State as its president, the Northern Baptist Convention on its finance committee, and the First Baptist Church of Cleveland as its honorary president. Deeply religious with the calm sanity of one whose art served those who sought out the secrets of the heavens, he is said to have remarked shortly before his death, "There is one thing no telescope will ever be able to do. It will never be big enough to see around the edge."

In 1871 Mr. Swasey married Lavinia Dearborn Marston who died in 1913. There were no children to survive him. Only the memory of a true gentleman remains. The great works and monuments to his industry and philanthropy keep this memory alive; and that asteroid named in his honor "Swazya."—G. A. S.

Facing the Tax Problem

(*Continued from page 612*)

be reduced if the social-security program is abandoned; it should be increased if unemployment fails to diminish at the rate assumed. It should of course be increased if inflation, another veteran's bonus, or other exceptional events should occur. The important point here is that there may be further increases in total government expenditures. There is little reason to expect a decrease in the total. It is reasonable, however, to expect that curtailment of federal expenses will almost offset the prospective increase in state and local expenditures. Nontax revenue which now supplies about 1.5 billions annually may be expected to increase to about 2 billions; but probably in 1940 some 16 billions of expenses will remain to be financed by loans or taxes.

With a tax burden which promises to remain so large, high efficiency will be demanded of our tax system. To this problem most of the committee's study was devoted. The report merits the thoughtful consideration of all conscientious voters.

BRIEFING THE RECORD

Abstracts and Comments Based on Current Periodicals

MATERIAL for these pages is assembled from numerous sources and aims to cover a broad range of subject matter. While no quotation marks are used, passages that are directly quoted are obvious from the context, and credit to original sources is given.

China's Highest Art

HARPER'S MAGAZINE

MIDSUMMER, better than any other season, provides the time and the occasion to think seriously of leisure and loafing. In midsummer men forget the cares of office, shop, and market place and recreate body and mind, their painfully acquired sense of duty appeased by the sanctions of custom and the policy of their employers. What better time, therefore, in which to listen to the Chinese scholar Lin Yutang who writes in the July issue of *Harper's* on "The Importance of Loafing?"

From a Chinese point of view, says this expositor of Oriental thought, the man who is wisely idle is the most cultured man. If men fail to enjoy this earthly existence we have, he asserts, it is because they do not love life sufficiently and allow it to be turned into a humdrum, routine existence. The idle life really costs so very little, he says in another place, as Thoreau took the trouble to point out; and mention of Thoreau is enough to send one scurrying back to "Walden," never read too often, to learn that we still live meanly, like ants. The nation itself, according to Thoreau, with all its so-called internal improvements, which, by the way, are all external and superficial, is just such an unwieldly and overgrown establishment, cluttered with furniture and tripped up by its own traps, ruined by luxury and heedless expense, by want of calculation and a worthy aim, as the millions of households in the land, and the only cure for it as for them is a rigid economy, a stern and more Spartan simplicity of life and elevation of purpose. It lives too fast. Men think that it is essential that the Nation have commerce, and export ice, and talk through the telegraph, and ride thirty miles an hour . . . . And if railroads are not built, how shall we get to heaven in season?

But to get back to the Chinese view—

We do not deny, says Dr. Lin, that efficiency gets things done and very well too . . . . Against the old contention, however, that we must all be useful, be efficient, become officials and have power, the old reply is that there are always enough fools left in the world who are willing to be useful, be busy, and enjoy power, and so somehow the business of life can and will be carried on. . . . . Our quarrel with efficiency is not that it gets things done, but that it is a thief of time when it leaves us with no leisure to enjoy ourselves, and that it frays our nerves in trying to get things done perfectly . . . . The tempo of modern life forbids this kind of glorious idling.

And thus, West meets East, in Thoreau and Dr. Lin. In the vacation leisure there is time to listen to these calm voices, for after Labor Day one becomes an ant again.

The Engineer and Government

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

SYSTEMS of government, not only in Europe but here in America, are in a state of flux, says Vannevar Bush, dean of engineering, Massachusetts Institute of Technology, member, The American Society of Mechanical Engineers, in a paper entitled "The Engineer and His Relation to Government," read at the Summer Convention, Milwaukee, Wis., June 22, 1937, of the American Institute of Electrical Engineers. Dean Bush's complete paper will soon be available in *Electrical Engineering*, published by the A.I.E.E., but certain portions of it are summarized in what follows.

Following some introductory paragraphs in which it is noted that many governments, under the influences of the complexity of modern life, are surrendering democratic for absolute systems of government, Dean Bush observes that our government is now of rather extreme democratic form, and that public opinion controls its trends in large affairs; hence its governing bodies and executives are bound to be men sensitive to, and able to cope successfully with, this opinion of the public.

However, Dean Bush continues, our government is called upon to decide momentous technical matters, most of which are so complex that they can be fully understood, if at all, only by experts. These questions involve finance, sociology, economics, and engineering. They cannot be grasped completely and intelligently by the general public or by the elected representatives of the people. How then are they to be wisely decided in a democracy?

Standing aside from the industrial system, and yet intimately connected with it, are the great professional classes, of which the engineer forms a part. What renders a man a member of this professional group is more than possession of special knowledge. The distinguishing characteristic, according to Dean Bush, is the possession of a philosophy and a point of view; the true criterion lies in the basis of motivation of the industrial.

Dean Bush then states that there is too little respect for genuine scholarship in this country and says that fundamentally the influence of the professional groups depends upon the development of this respect; moreover the influence of the professional man is needed in these times. It is the government that most needs this influence, but at this point in this country we proceed haltingly.

This brings Dean Bush to a consideration of the scheme of organization of professional groups in this country which he says "is a marvel to behold," and of their lack of concern in public affairs. Reviewing briefly engineering and scientific societies and their agencies, he finds that the nearest we come to having a mouthpiece for engineers generally on important matters is in the American Engineering Council, and this, he says, has not the intense interest and support of the profession generally, and its expressed opinions are to this extent ineffective. Reasons for this he gives.

Three laudable ideas are involved in the matter of a central

engineering organization, Dean Bush asserts: (1) Furtherance of the interests of the profession; (2) the bringing to bear of the influence of the profession on public affairs; and (3) the giving of direct advice to government departments or agencies on their specific problems.

Summarizing the first part of his address Dean Bush says:

There is real attention being given to the professional advancement and the technical interests of the profession. We have an enormously complex system of organization of scientists and engineers in this country, and yet no effective single central organization representing all engineers and expressing their viewpoint on public questions. We have an elaborate mechanism for bringing advice to bear on scientific and engineering problems as they arise in government, and this mechanism is not utilized to the full.

What is to be done about it? he continues. Certainly no solution lies in forming one more society to join the throng. Integration is indicated; and since societies now exist for all the express purposes we have considered, a duplication of effort by a newcomer would simply complicate matters. Rather, the existing mechanism should be simplified and strengthened.

Dean Bush discards as impracticable the possibility that an engineering society should take official and definite positions on public questions involving engineering.

The taking of stands, he says, should be left to a body having that as its primary function. That body should be made up of men of great distinction in the profession, chosen for the purpose by the membership of the profession directly. It should use every legitimate means to be well known to the membership, by questionnaires, publications, and by reasonable publicity in regard to its deliberations and findings. It should be absolutely without fear and without prejudice. Its pronouncements should be front-page news in every corner of the land. It should enter into any public question involving engineering as a right and without invitation. It should not hesitate to swing public opinion by rousing the profession when such action is indicated. In order that it may speak with a single voice it should represent engineers only, of course with deference to the opinions of other professional groups. We do not have this situation today. The metamorphosis of existing organizations, under the guidance of public-spirited engineers, may bring it to pass. As it proceeds it should have the aggressive support of every engineer who has the good of his country at heart, whether or not he agrees with its findings in every respect.

The concluding portion of Dean Bush's paper is a plea for the independent consulting engineer who should be supported by industry, by government, and by educational institutions, and an explanation of ways consulting engineers might be encouraged to make contacts with the government and the legal profession. His emphasis is on their maintenance of their independence. As long as this is maintained, he says, and there is effective guidance of affairs by an independent professional class, he has no fears for the future. A true democracy, given this support, can compete with dictatorship and prevail.

The concluding paragraphs of Dean Bush's paper are worthy of being quoted in full. He says:

The free operation of professional classes, motivated by public zeal and altruism, is an anchor upon which our democracy depends to hold it through the storm. There is a great obligation upon the professional man to speak clearly, to insist upon being heard, to maintain his independence. This obligation rests heavily upon engineers.

To be a professional engineer in the true sense does not require that we have some special set of relationships to society and to the organizations of which it is made up. It does require that the primary motivation be the acquisition of scholarship and its generous application to the needs of man.

To be an engineer in these days is to bear a proud title. To be able and willing to speak true opinions on the complex technical affairs of the day, without prejudice and free from control, is a privilege that is becoming rare in the world. Insistent upon his prerogatives, kowtowing to no man, respected because he speaks a truth the country needs to know, the independent engineer stands as an important member of the professional class, a strong bulwark against disaster which can guide our steps into the ways of pleasantness and into the paths of peace.

The Competitive System

JOURNAL OF THE FRANKLIN INSTITUTE

USING the petroleum industry as an example in a paper entitled "Industrial Growth and the Competitive System," J. Howard Pew, president, Sun Oil Company, in the June, 1937, issue of the *Journal of the Franklin Institute*, reviews the rapid expansion of the industry and the increase in the amount of known supplies of petroleum that has several times far outrun the estimates of geologists. The problem that this contradiction would have placed before a National Planning Board is sketched by Mr. Pew in the following words:

We may speculate with some interest as to what might have been the attitude of a National Planning Board if one had existed, in the year 1900, toward the automobile and oil industries of that day. There were then about 8000 motor cars in the country, consuming about 3,360,000 gallons of gasoline a year. That would operate the motor vehicles of today about an hour and a half! One may imagine Henry Ford, with his vision of the automobile's future, appearing before the planning board, to ask that in its program for the next two or three decades it consider providing a few billions of capital, along with the material and labor, for his industry. The planning authorities would have recognized Mr. Ford as a mild lunatic. They would have asked where he hoped to get the gasoline to operate all these cars, pointing out that neither the gasoline nor petroleum from which to make it was anywhere in sight. So Mr. Ford's demands would have been rejected. A sophisticated public would have laughed at Ford when the planners set down genius as insanity and inventive capacity as lunacy—and that would have ended foolish talk about horseless carriages and flying machines.

Fortunately, there was no planning board to head off Mr. Ford's folly. Without bothering about where his gasoline would come from, he went ahead and presently was turning out 1,000,000 cars a year. And, there being no planning board to interfere, the petroleum industry kept right in step, always meeting the demands. Spurred on by the hope of profits, it set about boring more holes in the search for more petroleum, and sometimes finding it; it tried out new areas, brought in new producing fields; used geology and geophysics as aids in its search; developed deeper drilling; built pipe lines and tank ships to provide cheap transportation; erected more, and bigger, and increasingly complex refineries. And so, each year accomplishing things that a year earlier would have been impossible, the oil industry kept always ahead of the thirst of those multiplying millions of motor cars.

By 1925, 20,000,000 motor vehicles were calling for—and getting—nearly 10,000,000,000 gallons of gasoline. Public demand was pushing the automobile industry, and the automobile builders were urging on the petroleum industry; and all

were marching on together. Unfettered enterprise, initiative, invention, and competition were accomplishing the things that our hypothetical planning board of 1900 had recognized as beyond the range of reason.

Mr. Pew then outlines what the increased demand for gasoline actually accomplished for the petroleum industry and the far-reaching effects of the development of the automobile industry. Continuing, he says:

Let me repeat that these things were accomplished by the most competitive businesses in the country; the direct result of constant, unrelenting competition. The evidences of that competition are brought to you whenever you look at the advertising columns of newspapers or magazines, at billboards or electric signs; or when you listen to the intriguing message with which the radio announcer points his morals and adorns his tale. Mass production, constantly improving methods, have made for continuously lower prices and wider markets. Profits have come from increasing volume at lower unit prices; from passing on to the consumer the benefit of every advance.

There hasn't been an iota of philanthropy, an ounce of idealism, a scintilla of unselfishness; nothing but sound business principles, working for profits, in an atmosphere of free enterprise and unfettered competition.

Following a brief summary of the extent and development of the petroleum industry which now employs more than 1,000,000 workmen directly and, through its purchases of steel and other products which it consumes, more than 800,000 additional workers, Mr. Pew says:

This has been the experience not only of the petroleum industry, but of all the others of the automotive group. No economic directing authority could possibly have foreseen, plotted, planned, and organized such an achievement. No trust or combination, private or governmental, could have accomplished it; it could only have been conceivable in virtue of wide-open invitation to all the genius, inventive capacity, organizing ability, and managerial skill of a great people. Nobody must be barred, nobody's invention rejected, nobody's idea left untried. Everybody must have his equal chance; and under our system of free enterprise and equal opportunity, everybody got just that chance. The result is the achievement that has fairly made over the face of industrial America.

Durable Goods and Depressions

THE CLEVELAND TRUST COMPANY BUSINESS BULLETIN

CONCERN of mechanical engineers with durable goods and depressions is sufficiently keen to warrant the following quotation from the June 15, 1937, issue of *The Cleveland Trust Company Business Bulletin*.

An economic theory to explain the causes of depressions was recently expounded by the Secretary of Agriculture in a series of lectures at the University of North Carolina. The theory is in brief that corporations making large profits in a good year tend to spend them in the following year for expansions and equipment consisting of durable goods, and that by the third year there has resulted so great an overproduction of such goods that industry slows down and there is a depression. This doctrine is clearly important, both because depressions constitute our most serious economic and social problems, and because this appears to be an exposition of the economic philosophy of the national administration.

The argument as reported in the New York *Herald Tribune* is as follows: "In the past, excess savings have resulted in the following year in great activity in the building of factories, the extension of telephone lines, the repairing of railroad facilities, etc. For example there was a great increase in savings as compared with the preceding year in 1919, 1922, 1925, and 1928. One year later, or, in other words, in the years 1920, 1923, 1926, and 1929, there was unusual expansion in the heavy or durable-goods industries. And one year later, or, in other words, in 1921, 1924, 1927, and 1930, there was business recession." The remedy proposed is for the government to take through taxation "a considerable proportion of these excess savings," to prevent "unwise investment and harmful speculation."

The solid line in Fig. 1 represents for all corporations the net income after taxation during the 26-year period from 1909 through 1934, which are the only years for which we have complete data. The dashed line represents the physical volume of production of durable goods during the same years. Both lines are drawn on the basis that the averages for the entire period are taken as being equal to 100. An inspection of the lines will show that the sequences mentioned by the Secretary are all present.

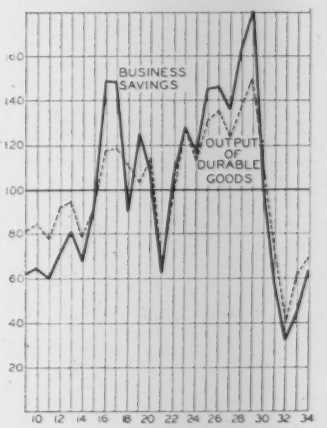


FIG. 1 SAVINGS AND PRODUCTION
(Average, 1909–1934 = 100.)

A more important feature of Fig. 1 is the clearly evident fact that the two lines tend to move upward and downward together. Corporations tend to have good profits in the years of active business when the production of goods is large. Now whenever business activity has expanded for two years just previous to a recession the sequences mentioned by the Secretary are bound to appear. Unfortunately, this does not mean that the causes of business depressions have been discovered. It simply means that business profits tend to increase in the good years when industrial production expands, and to decline in the poor years when production shrinks.

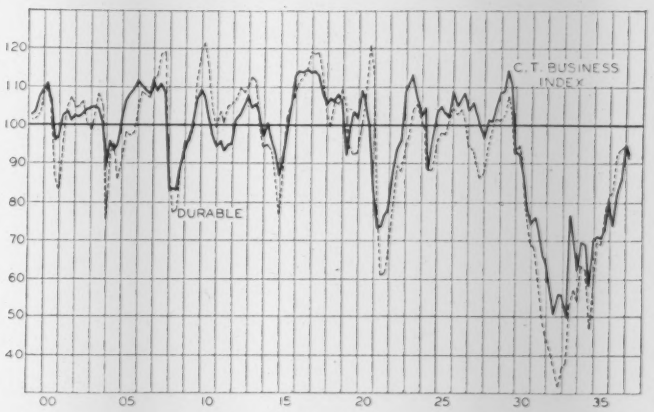


FIG. 2 BUSINESS INDEX COMPARED WITH DURABLE-GOODS OUTPUT AS PERCENTAGE OF NONDURABLE

It is a great pity that we cannot arrive with the Secretary at the simple conclusion that merely because the depression years follow the years of good profits and large production they must be caused by them, and that the recessions might be largely prevented by taking through taxation a considerable proportion of the profits in the good years. The attempt to avoid depressions

by preventing prosperities would probably merely result in perpetuating the depressions. Nevertheless business cycles do mainly result from wide fluctuations in the production of durable goods as explained in what follows and in Fig. 2.

There is convincing statistical evidence that the activity from prosperity down to depression and back again results chiefly from great, wave-like variations in the volume of production of durable goods. The Federal Reserve authorities classify as durable goods those industrial products that are made from the lasting materials such as the metals, lumber, stone, clay, and glass. The nondurable goods are made from the shorter lived materials such as chemicals, foodstuffs, leather, paper, rubber, textiles, and tobacco.

Since the durable goods may be made to last for long periods their replacement may easily be postponed when business prospects are not bright, and so purchases of these goods are largely optional. However, it is frequently impossible to postpone buying such goods as food, clothing, gasoline, tobacco, soap, and so on, and therefore the purchases of nondurable goods are largely obligatory. The volume of production and use of nondurable goods does not fluctuate greatly as between good business periods and hard times, while the volume of output of durable goods does vary widely.

The volume of production of durable goods as measured by the Federal Reserve indexes is about 85 per cent as great as that of the nondurable goods. In preparing Fig. 2 the monthly figures of production of durable goods since 1899 were multiplied throughout by a constant so as to make the sum of the monthly figures equal over the long period to those for nondurable goods. Then there were computed for all months the percentages that the durable-goods data were of those for nondurable-goods production. The result is shown in the dashed line which was plotted at quarterly intervals.

The solid line shows the business activity index of the Cleveland Trust Company, which is in reality an index of the volume of all industrial production, including mining. The fluctuations of the dashed line are wider than those of the solid one, but the turning points of the major swings and most of the minor variations are closely similar. The dashed-line index made by finding the percentage that the production of nondurable goods was of that of durable goods is by itself a fairly good index of business activity.

It is noteworthy, nevertheless, that the degrees of severity of depressions and of excesses of booms in general business have not been closely related to the preceding fluctuations in the production of durable goods. The highest peak in the dashed line was in 1910, but the following depression was a mild one. The dashed line was never far above the 100 level during the prosperity from 1923 through 1929, but the following depression was the greatest on record.

Biomechanics

ARCHIVES OF SURGERY

BECAUSE it was the privilege of MECHANICAL ENGINEERING to publish a paper by Charles Murray Gratz, M.D., covering that portion of his work in biomechanical studies of fibrous tissues that described his adaptation of engineering methods and concepts (see the issue for April, 1935, pages 217 to 220), a brief résumé of the completed work, appearing in the *Archives of Surgery*, for March, 1937, may be of interest.

Doctor Gratz's paper presents the results of determinations of tensile strength, elasticity, and proportional limit of selected fibrous animal tissues and applies the findings to problems of clinical surgery. Dr. Gratz says that the engineering methods he employed, familiar to engineers as those used in investigating the strength of materials, combined with his histologic studies, showed that the physical properties of tendons and fasciae are comparatively similar, thus making the research and clinical work on surgical procedure on tendons at least partially applicable to those on fasciae. Fasciae are condensed connective tissues forming sheets or layers for the investment of organs or the insertion of muscles of the body. To that range of the stress of these materials below what engineers call the "proportional limit," Dr. Gratz has applied the term "physiologic range of elasticity;" and in cases of injury, rupture of the tissue depends on whether or not the load exceeds this range of elasticity. If two persons are subjected to a similar amount of stress, permanent damage may be sustained by one, while the other may have only a trivial injury. On the basis of the engineering definition, the physiologic range of elasticity would have been exceeded in the first patient and not in the second. In the first patient the tissues would have lost their power of recovery; in the second this power would have been unimpaired. The physiologic range of elasticity of bodily tissue was measured by Dr. Gratz and the limit was found to average about 7100 lb per sq in.

Dr. Gratz found that shearing stress and injury markedly diminish the physical properties studied, and the findings have been clinically applied to devise a physiologic technic of fascial transplantation. Reference is made to the rôle of the fascial planes in the mechanics of the soft tissues of the locomotor apparatus, and the functional mechanics of soft structures are considered in relation to the rôle of fascial adhesions in pain low in the back. Dr. Gratz pays gracious tribute to the engineers who advised him in his engineering approach to his studies.

Toward the Goal of Science

SCIENCE

BECAUSE engineers perform the function of applying the discoveries of the physical sciences, at least, to the uses of mankind and occupy a unique position in an industrial civilization in respect to the impacts of science on men and their institutions, an address by F. R. Moulton, delivered before the Lancaster, Pa., branch of the American Association for the Advancement of Science and reported in the June 18, issue of *Science* has more than usual significance. Dr. Moulton spoke of the goal of science as an intellectual and moral world in tune with the uniformities which we know as "the laws of nature." That goal, he said, transcended in importance every other objective of science, and scientists would, he hoped and believed, give it more and more attention. He said in part:

In speaking of the ultimate goal of science, I do not, of course, think that scientists should attempt to hitch their wagon only to a very distant and perhaps unattainable star. There are many intermediate objectives worthy of their attention. For example, I think that scientists should very often consider science in the broader aspects of its effects upon human beings. It has sometimes been suggested that scientists should undertake to settle the problems of economics and sociology and government by the methods which they have found effective in the natural sciences. But it is probable that in those strange and wholly different fields workers in the natural sciences would be about as incompetent as politicians would be in a chemical laboratory. It would be unsafe to assume that they are masters of methods that are fundamentally different from those which

other intellectually honest men attempt to use in much more difficult fields. It would be even more unsafe to assume that, as compared with men in business and other professions, they are exceptionally altruistic. The only assured fact is that they are introducing revolutionary factors in the world and, therefore, that they should feel a heavy responsibility for examining the results of what they are doing. With deep humility they should cooperate with men in other fields to discover how society may best use the titanic forces which they are placing at its command. They should do this thoughtfully and persistently lest that which so far has on the whole been good should eventually turn out on the whole to be bad.

In certain respects the steep trail science has been traveling in recent decades must soon change to a gentler slope. . . . Science is now in the rapidly growing springtime of its existence. Its roots are in fertile soil and its branches are rapidly pushing out in all directions. Instead of attempting the impossible task of stopping its growth for a period, it will be better to direct its development so that its fruit shall be good. This is why I am urging that scientists consider carefully the effects of what they are doing.

There has often been an aloofness on the part of those who work in the natural sciences from the remainder of the world. Sometimes we have heard boasts that the results of an investigation never could be put to a practical use. Although the richest rewards of scientific research are aesthetic, the pure joy of discovery, yet that fact does not justify any touch of snobbery on the part of scientists, for other men may get similar pure enjoyment out of the things they do. No one is qualified to say that what he does is in any way more important, except to himself, than what another one may be doing. There is no good reason for thinking that the fields of honest endeavor, however much they may differ otherwise, are on essentially different levels.

In view of the complexities and importance of the humanities, they have been given too little attention. When I make this statement, I am not expressing any approval of immature theories respecting the desirability of more numerous social controls. On the contrary, I think that enforced restraints into standardized patterns will destroy our capacity for improvement. I am thinking, rather, of investigations in psychology, economics, political science, social science, and related fields from the objective point of view adopted by biologists, for example. I am thinking, too, of industry as not only depending on many sciences, but as being in a real sense science itself. Science pursued in this broad sense will enrich itself and the world.

Health Protection of Welders

METROPOLITAN LIFE INSURANCE COMPANY

IN A 28-page booklet issued by the Metropolitan Life Insurance Company, New York, N. Y., entitled "Health Protection of Welders," the possible effects of metal fumes and of light and heat rays on the health of welders are discussed.

The principal hazards are listed as: (1) Electric shock and burns; (2) radiant energy in the forms of invisible ultraviolet rays, visible infrared rays, and visible light rays of excessive intensity; (3) gases, fumes, and dust, which include the gases generated by the arc or flame (such as nitrous gases, carbon monoxide, carbon dioxide, and fluorine), metallic oxides and metal and mineral dusts and fumes volatilized by heat from the materials being welded or their coatings, or from the coatings of the electrodes in arc welding, or from the flux used (lead, zinc, manganese, cadmium, phosphorus, sulphur, arsenic, selenium, and silicon); and (4) miscellaneous hazards, such as air pollution in unventilated places and injuries due to the worker's posture. The booklet discusses these hazards and makes suggestions for protection from them.

Automatic Transmissions

S.A.E. JOURNAL

REVIEWING automatic transmissions—past and present, domestic and foreign—for automotive vehicles, P. M. Heldt presents in the May, 1937, issue of the *S.A.E. Journal* a number of illustrated descriptions of these devices. Transmissions, says the author, may be divided into stepped and continuously variable types, either of which may be controllable or automatic. With some stepped transmissions, generally called "full automatic," the ratio of crankshaft revolutions to propeller-shaft revolutions is always the same for any given car speed or engine speed, which means that the change from one ratio to another always occurs at the same car speed, leaving the driver no control. It is now generally admitted, says the author, that this arrangement is undesirable. Transmissions with which the driver has a choice of ratios at any point of the speed range and in which changes in ratio normally occur automatically are called "semiautomatic."

First is described the Strong reversible roller ratchet. From this the author proceeds to a description of the de Lavaud automatic transmission with wobble plate and roller ratchet with which it is possible to keep the engine operating at practically full torque, regardless of the speed of the car, and the latest development of the "variable-throw" automatic transmission, known as the R.v.R. torque converter used in the Minerva front-drive car.

Passing to hydraulic transmission, the author classifies two types, the hydrostatic and the hydrodynamic. In the former type the working fluid is put under pressure and set in motion by a pump, and the fluid moved by this pump acts on the pistons of a hydraulic motor. In hydrodynamic transmissions a fluid is set in motion by an impeller provided with blades, and its kinetic energy is expended on the blades of a driven member. Hydraulic couplings and torque converters can be combined with mechanical units in various ways to secure automatic changes of gear ratio with high efficiency of operation under most driving conditions. The Lysholm-Smith hydraulic converter is illustrated and described as an example of this type.

The use of inertia or centrifugal force of moving weights to transmit power from one shaft to another and to vary the ratio of the torques on the two shafts is next described, and the Spontan automatic transmission, with inertia weights and eccentrics, is illustrated. Other infinitely variable transmissions using inertia masses described by the author are the Constantinesco and the Hobbs.

The author comments that considering the great technical talent and the large financial resources of some of the men who have devoted themselves to this type of transmission, and the meager results achieved by them to date, it does not appear that this principle holds out any great promise as to profitable applications in the automotive field.

Next considered by the author is the self-shifting transmission with either three or four definite ratios in which the change from one ratio to another occurs either entirely automatically or is brought about by the operator by acting on the speed of the engine (by means of the accelerator) or on the

speed of the car (by means of the brake). Two devices extensively used are the automatic friction clutch and the overrunning or roller clutch. After some comments on vacuum-controlled and centrifugally controlled clutches the author describes the Sturtevant, no longer on the market; the semi-automatic Yellow Coach transmission; the Macallen torque-balancing mechanism; an automatic shift for conventional three-speed-and-reverse transmissions invented by D. C. Prince and applied by him to a Plymouth car provided with a vacuum-operated automatic clutch and a free-wheeling unit; and the Tyler Unimatic Motorcar Control, comprising a three-speed transmission of constant-mesh type with individual multiple-disk clutches actuated by the inlet manifold and a main clutch that transmits power for all of the gears.

Next is discussed the use of the differential gear in automatic transmissions with which many inventors have been concerned, and this leads to a consideration of the principles of an electric differential transmission. Following is mention of the Entz transmission of the Owen Magnetic car without the differential gear, making use of the "feed-back" principle, and of a description of the Electrogear differential transmission being developed in this country. The article concludes with a description of the hydrodynamic type of differential transmission known as the Bendix Turbo Flywheel Gear.

Miniature Ball Bearings

MACHINERY (LONDON)

A SWISS manufacturer of watch parts, according to *Machinery* (London) for June 17, 1937, has developed and is manufacturing on a commercial scale ball bearings so small that they can be substituted for ruby, sapphire, and plain bearings in all forms of clockwork, motors, delicate machines, and sensitive measuring instruments. Some of these miniature bearings are produced in quantity and to standards of extreme precision in overall sizes, including the race, less than that of an ordinary pin head, overall dimensions actually ranging from 1.5 mm upward. It is said that complete bearings of only 1 mm overall diameter will soon be available.

Tests have been made to find out the reduction in friction resulting from the use of the miniature ball bearings instead of jewels and pivots. The mean damping time for rotational motion in identical conditions was eight times longer than for plain, and 20 times longer than for tapered pivots. An oscillation test gave similar results. Unlike plain bearings, it is said, these ball bearings have an extremely low coefficient of friction and approximately the same force is required for starting as when running.

When correctly mounted these bearings exhibit negligible wear, even after a long period of use. They withstand shock better than jewel bearings, which is especially important in aircraft instruments.

The miniature bearings of small size contain three balls; the largest contain eight. It is claimed that they operate satisfactorily up to 10,000 rpm. They use only 15 per cent of the oil required for plain bearings and hence need not be lubricated for years.

A wide variety of engineering applications is indicated by the following list of types which are available or in course of production: Ball bearing with tapered pivot; ball bearing which can be dismantled by withdrawing the inner race without removing the cover; ball bearing with outer race bored for additional lubrication or for a shaft; reinforced ball bearing with large or medium bearing radius; oblique ball bearing with heavy inner race; flexible and adjustable ball bearing; adjustable elastic ball bearing with compensated springs.

The standard range is said to include also ball bearings which can withstand radial and axial stress. These include bearings intended for use with spindles that are free to move axially into a definite position during rotation; bearings for cylindrical flanged pivots, and radial ball bearings with thrust plate. The bores of these bearings are machined to ± 0.0001 in.

An Infinitely Variable Gear

FLIGHT

A FORM of hydraulically controlled mechanical torque converter having infinitely variable characteristics over almost any range has been designed by T. Watson Paterson, of Liverpool, and is described in the March 11, 1937, issue of *Flight*. The designer feels that the device should lend itself to application as a self-contained and concentric coupling in an aircraft propeller hub to provide a variable gear ratio.

The mechanism, shown in Fig. 3, is basically a right- and left-

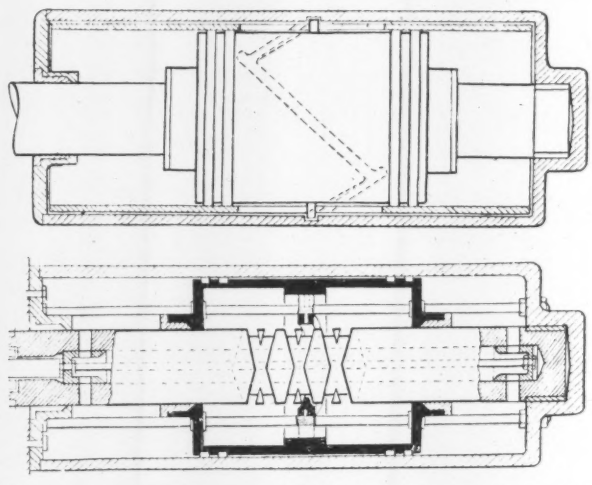


FIG. 3 TWO SECTIONS THROUGH THE PATERSON TORQUE CONVERTER

(In the upper is seen the reciprocating piston with its pins engaging the continuous cam groove in the outer cylinder. The lower shows the crossed thread on the power shaft, with its rocking nut.)

hand (crossed) thread on the power shaft on which is reciprocated a double-ended piston, the piston having inside its body a rocking nut which engages with the threads and travels up one and down the other continuously. Surrounding the piston is a cylinder which is free to rotate on the power shaft, but a continuous cam groove in the cylinder wall engages with studs on the piston (or vice versa) so that reciprocation of the piston results in rotation of the cylinder.

The overall reduction of speed between the driving shaft and the cylinder is, of course, a function of the pitch of the screw thread and of the cam groove. Thus, if the screw shaft rotates four times to one cycle of piston reciprocation and one piston cycle rotates the cylinder through half a revolution the ratio is 8 to 1, and so on. Of course any ratio from, say, $1^1/_2$ to 1 down to 30 or 40 to 1 may be selected, but whatever mechanical ratio is arranged becomes the lowest positive drive that will be provided and between it and a direct 1 to 1 ratio a hydraulic control gives an infinitely variable regulation.

This control is quite simply arranged. The double-ended

piston reciprocates within, and rotates, the cylinder. Obviously, if the reciprocation of the piston should be checked the whole assembly would be compelled to revolve as a solid mass at the speed of the screw driving shaft. To effect this impedance to piston reciprocation the spaces between the closed cylinder ends and the piston ends are filled with oil. A communicating duct is drilled through the driving shaft and controlled by a valve which opens or restricts both ends simultaneously. With the duct fully open the reciprocation of the piston is not impeded, the oil being transferred idly from end to end and the full mechanical "gear" reduction between drive shaft and cylinder is obtained. But as the duct is restricted the impedance to piston travel results in its tending to revolve with the drive shaft and in turn to carry the cylinder with it at the same speed.

When the duct is closed completely the piston no longer reciprocates because the oil cannot be displaced, and the whole mechanism runs solidly as a unit. Actually the device can be made to function automatically, because if the oil ports and duct are dimensioned according to the power, speed, and loading involved, the restriction on oil transference from end to end of the cylinder will vary with the piston speed. Thus as the loading on the propeller decreases the engine speed would tend to rise and with it the rate of the piston reciprocation.

Beyond a certain rate the piston would be impeded by restriction of oil flow and the propeller speed would then tend to rise, thereby imposing greater load on the engine, checking its increasing speed, and re-establishing balance between power and load. External control could therefore be limited to complete closure of the transfer duct when stable conditions of normal power, speed, and load were attained.

The mechanism, being entirely self-contained and concentric, should be adaptable to the hub of a propeller. Should the hydraulic element fail for any reason, and particularly if the fluid should be lost, the low gear ratios (mechanical) would come automatically into operation.

Milling Speeds and Feeds

AMERICAN MACHINIST

FACTORS affecting milling speeds are listed by O. W. Winter in the May 5, 1937, issue of *American Machinist* as follows: (1) the material to be milled, (2) material of which miller is made, (3) depth of cut, (4) rate of feed, (5) coolant used and method of delivering coolant to cutter, (6) type of cutter, and (7) nature of the cut.

A table giving average peripheral speeds in feet per minute when milling various types of cast iron, steels, and common nonferrous metals and when using high-speed-steel cutters is provided by the author. Factors are also provided for use when cutters made of other materials are used.

A good coolant for milling, says Mr. Winter, must possess good lubricating qualities to reduce friction, particularly that produced in the early stages of chip formation. It must also possess good cooling qualities. Of even greater importance is the volume of coolant delivered. The copious flow of coolant desired should not be squirted under high pressure, and should be applied at the point where the cutter enters the work. Thus adequate chip space between cutter teeth is required.

Deep slotting cuts demand slower cuts than shallow slab-milling cuts, one important factor involved being the ability to provide coolant at the cutting edge.

Factors other than cutter speed that affect milling feeds are (1) rigidity of setup, (2) power available, (3) finish desired, and (4) type of cutter used.

Generally speaking a milling setup cannot be too rigid. Machine spindle and slide bearings should be fitted snugly and the work should be well supported with plenty of mass in the fixture. The arbor should be supported as near the cutters as possible. Friction alone should not be relied upon to drive the cutter; a key of hardened steel should be used.

Quality of surface finish is affected primarily by feed per revolution. The number of teeth in the cutter has little effect on "revolution marks" left on the work. As a general rule the following feeds per revolution can be used with plain helical and side-milling cutters to produce the finishes indicated: Fine finish 0.025 in., finish to be scraped 0.035 in., commercial finish 0.035 to 0.050 in. Face mills and shell end mills will produce the same finishes with the following feeds per revolution per inch of cutter diameter: fine finish 0.030 in., finish to be scraped 0.035 in., commercial finish 0.040 to 0.045 in. The deeper the cut and the greater the number of teeth in contact with the work the greater the total pressure on the cutter. Hence a coarse-tooth cutter is usually under less total stress and puts less pressure on the work than does a fine-tooth cutter.

A table is included giving values for allowable feed per tooth when cutting cast iron and when using a variety of types of milling cutters. Factors for converting these values to those desirable for cutting steel, aluminum, and brass are mentioned.

Four speed and feed charts for face and slab milling of cast and malleable iron and for face and slab milling of steel are a feature of the article.

Sliding Metal Surfaces

ENGINEERING

FROM the May 28, 1937, issue of *Engineering*, has been taken the following résumé of a paper by F. P. Bowden and T. P. Hughes read at a meeting, in April, 1937, of the International Association for Testing Materials. The paper is entitled "The Surface Temperature of Sliding Metals and Its Influence on Flow and Wear."

Dealing with the measurement of surface temperature, the authors pointed out that if two different metals were allowed to slide over one another, their rubbing contact might be used as a thermocouple, and the surface temperature could be measured. Direct experiment showed that this surface temperature depended upon the load and upon the speed of sliding, and might be remarkably high. Under many conditions of sliding, it was sufficiently high to cause a real melting of the metal. Curves were given showing the surface temperature reached by various metals slid over a polished steel surface, the surface temperature rising until it reached the melting point. Even if the surfaces were lubricated or flooded with water, the local high temperatures were still developed. The local surface temperature of metals lubricated with a good commercial lubricant might be over 600 C, although the metals were sliding smoothly and appeared to be quite cool. This was an important cause of the breakdown of lubrication films. Wear would take place at the hot spots, which might weld together the surfaces seizing. Dealing with the influence of the relative melting point on the flow and wear of solids, the authors said that the processes of wear, surface flow, and polishing should be greatly influenced by the relative melting points of the sliding solids. If, for example, a polisher softened or melted at a lower temperature than the solid, it would melt and flow first and have comparatively little effect on the solid. Surface flow, polish, and wear readily

occurred if the conditions were reversed. The amount of wear between sliding surfaces should be influenced not so much by their properties at room temperature, as by their relative mechanical properties at the high temperatures of sliding.

Better Cast Iron

IRON AGE

IN A paper entitled "Gray Cast Iron," Sam Tour, vice-president, Lucius Pitkin, Inc., reviews, in *Iron Age* for June 24, 1937, modern developments in this important material, with references to significant literature covering the subject. Improvements through the years in gray cast iron are summarized in a table, while other tables present collateral evidence of similar improvements in specifications for malleable iron, steel castings, and nonferrous alloys.

The first table referred to shows that in 1918 iron castings were divided into three types—light, medium, and heavy—and carries specifications for tensile strength of 18,000, 21,000, and 24,000 lb per sq in., respectively. By 1936, however, the gray-iron industry had advanced to a position where A.S.T.M. new tentative specifications list seven different grades of cast iron running from 20,000 to 60,000 lb per sq in. tensile strength. Along with this advance in tensile strength have been corresponding advances in load-carrying ability as indicated by transverse tests. The industry also now has available high-test heat-treated cast iron. One of these has a tensile strength of 75,000 lb per sq in., 14 per cent elongation, and the other a strength of 107,000 lb per sq in., $2^1/_2$ per cent elongation.

In addition to the regular grades of nonheat-treated cast iron indicated in A.S.T.M. specifications there are now available numerous other types of gray iron containing various alloy additions, such as nickel-chromium cast iron, molybdenum cast irons, and specially treated cast irons, such as Meehanite. Most of these special cast irons are made by processes wherein it is endeavored to control accurately the graphitization that takes place during cooling and thereby to improve the mechanical properties of the metal as well as make more uniform the properties in thick and in thin sections of individual castings.

Another worth-while development in the cast-iron field mentioned by Mr. Tour is that of permanent molding pioneered by the Holley Carburetor Co. The process is said to produce gray-iron castings of uniform properties on a production scale somewhat beyond that which could be obtained in sand-casting practice.

Machinability, says Mr. Tour, is not necessarily directly proportional to softness of gray iron nor is its graphitic content; most important is the condition in which combined carbon is present. A photomicrograph is shown of a cast iron containing 3.55 per cent total carbon, 0.51 combined carbon, 2.35 silicon, 0.62 manganese, and 0.42 phosphorus. It is explained that the structure is made up of a network of phosphide eutectics embedded in a matrix of pearlite and that shot through the whole are numerous flakes of graphite. Pearlite is made up of alternate layers of soft iron known as ferrite and hard iron carbon compound known as cementite. This structure of pearlite makes it possible for the cutting edge of the tool to travel through it without balling up on the point of the tool and ruining the cutting edge. It also makes it possible for the cutting tool to travel through the network of hard phosphide eutectics and break it up without damage to the tool. If instead of having this matrix in the form of pearlite it were present in the form of soft iron or ferrite, there would be a soft iron binding material enclosing a hard and brittle phosphide eutectic. The structure would be comparable to that of a grinding wheel where the hard particles wear the tool.

A second photomicrograph shows a cast iron containing 3.42 per cent total carbon, 0.04 combined carbon, 2.17 silicon, 0.61 manganese, and 0.30 phosphorus. Although the phosphorus is lower than in the previous specimen, the matrix is ferrite and not pearlite, and the material rapidly wears the cutting tool; hence it is not a good machinable material. The main difference between the two materials is the amount of combined carbon present and its disposition within the iron. Were the combined carbon present as large particles of hard iron carbide, it would still be difficult to machine but as it is present as pearlite it becomes a readily machinable material.

Railroad Air Conditioning

ASSOCIATION OF AMERICAN RAILWAYS

SUPPLEMENTING the Summary Report, noted in this section in our April, 1937, issue, the Division of Equipment Research of the Association of American Railways issued in April, 1937, its Engineering Report on Air Conditioning of Railroad Passenger Cars. The engineering report is designed to meet the needs of the air-conditioning engineer and railroad operating personnel. It presents the results of laboratory tests of 15 air-conditioning systems, 6 drives, and 14 cars and of road-performance tests of 594 cars. A third report is to be prepared to give results from tests on air-conditioned Pullman cars in regular service.

Although the engineering report is too extensive for satisfactory abstracting, a résumé of the findings should be helpful. For four types of systems (ice-activated, electromechanical compression, steam-ejector, and direct mechanical compression), gross installation costs, fixed charges, operating, and maintenance costs are summarized. Test results are reported for the air-conditioning equipment and drive mechanisms made by numerous manufacturers.

With a 20-degree difference between outside and inside temperatures it was found that the refrigeration required to absorb the heat transmitted through the car structure varied from 1.3 tons in the best insulated car to 3.1 tons in the worst insulated car in approximately still air. It is said that additional study of the subject of insulation is needed. Approximately 3 tons of refrigeration is required for an average passenger car to provide for (*a*) a heat load due to a 20-degree difference in outside and inside temperatures; (*b*) the heat load due to the sun; and (*c*) an air motion of 50 mph.

As to methods of delivering air to the car, it was found that the inside center duct was most effective. In descending order of effectiveness other methods ranked as follows: Double outside duct, single outside duct, center bulkhead, and double-end bulkhead.

With outside temperature of 84 F, 30 min was required to precool a car to 74 F; to cool to 78 F with 100 F outside required 3 hr. Requirements for summer air conditioning as regards inside temperature, relative humidity, temperature distribution, air movement, and volume of fresh air per passenger are given. It is stated that full automatic control of both temperature and humidity is essential.

Elements of the air-conditioning problem on which further study is said to be needed are: (1) Insulation, to determine the most suitable kinds, the economic limits to its use, and whether reductions in heat transmission can be effected by changes in car construction; (2) filters; (3) windows; and (4) odors.

Rail Motor Cars

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

IN A statement by L. Dumas, special reporter, Section 2, Locomotives and Rolling Stock, summing up reports on the evolution of the rail motor car at the thirteenth session of the International Railway Congress Association, Paris, 1937, to be found in the June, 1937, issue of the *Monthly Bulletin* (English edition) of the Association, appears the following summary:

Satisfactory technical solutions have been found in the course of the last two or three years to the speed, acceleration, braking, and safety problems.

The future of the rail car now depends on the solutions that will be adopted as regards comfort, economical maintenance, and capacity. This future also depends on future improvements of the track (curves, superelevation, elimination of rail joints or reduction of their number), and on the adaptation of the operating methods to the rail motor car.

Rail car Diesel engines can be divided into three classes:

(*a*) 600- to 1800-hp engines, relatively heavy, but very economical as regards working and maintenance; such engines are used extensively in the United States of America.

(*b*) 300- to 600-hp engines weighing about 11 lb per hp, as adopted by most European railways.

(*c*) 200- to 300-hp engines, among which the Czechoslovakian, German, and French horizontal engines deserve special mention.

By the use of supercharging, which tends to extend, the weight-power ratio of engines can be reduced; improved behavior of the motion and better dissipation of the lost heat units are also obtained.

Mechanical transmissions are quite satisfactory, as regards weight, cost, and efficiency, up to 300 hp. Mechanical transmissions for 450 and 500 hp are being tested in Italy and in France.

Electrical transmissions are now fully perfected for all powers, and are preferred for services on mountain lines and for multiple-unit working.

Hydraulic transmissions have made definite progress in the course of the last two years, in respect of all powers and engine speeds, in Austria and Germany.

In order to reduce hunting movements to a minimum and to obtain improved comfort, railways are now currently using wheel tires coned 1 in 40, cylindrical tires, multiple-suspension gear, and rubber shock absorbers. Such devices have not given rise to any difficulty and their use can be recommended.

Some administrations also use devices to damp out hunting movements and vertical vibrations, trucks (articulated or not) with 6 or 8 wheels, loose wheels revolving about fixed axles, axle boxes without axle guards, etc. All these solutions have given them satisfaction.

Block brakes are most generally employed at present; they are electrically controlled in certain countries (U. S. A., Czechoslovakia) and improved by the use of Decelakrons or self-regulation in proportion to the running speed. Among new brakes, the disk brake, the eddy-current brake, and the N.R. brake with double shoes should be mentioned.

Soundproofing and air conditioning are particularly resorted to at present in order to increase comfort.

Steel-tired vehicles—although they cannot claim the same comfort as pneumatic-tired vehicles—can be improved by means of double partitions with air cushion; all openings should be carefully stopped up, and plates lined with pulverized felting in order to avoid vibrations.

Air conditioning, and air cooling in summer, are particularly appreciated in vehicles with fixed window lights.

Maintenance costs and amortization charges are the biggest items in the cost price.

The first cost of American rail cars is high, but their maintenance costs are reduced to a minimum; in Europe, the desire for lightness has generally led to cheaper construction, which entails higher maintenance costs.

It would be desirable that the railways agree to calculate in a uniform way the coefficient of use of their rail cars and their cost price.

Most administrations tend to increase the capacity of their rail cars, so as to be able to substitute them for steam trains on an increasing scale. The question is to remain very much below the cost per mile of a train.

As regards general design, various solutions are being resorted to; observation rail cars, twin rail cars, or single rail cars coupled together, rail cars hauling trailers, multiple units of 3 to 17 vehicles.

It would be desirable for the railway administrations to adopt a common test method for ascertaining the characteristic constants of their rail cars. On the other hand, the nominal power of engines should be given the same definition in all countries.

Industrial Water Supplies

INDUSTRIAL AND ENGINEERING CHEMISTRY

IMPORTANT factors relevant to practically all industrial water supplies are listed by Sheppard T. Powell and Hilary E. Bacon in an article to be found in the June, 1937, issue of *Industrial and Engineering Chemistry*. The principal factors are:

(1) Availability and seasonal fluctuation of water from underground and surface sources.

(2) Chemical composition and physical characteristics of all supplies under consideration.

(3) Qualities revealed by microscopic and bacteriological analysis.

(4) Variation in quality which may be anticipated on the basis of past records.

(5) Predicted influence on water quality of domestic or industrial waste disposal, existing or anticipated.

(6) Water requirements of the proposed plant for processing, cooling, steam generation, sanitary uses, and fire protection.

(7) Availability and cost of municipal water supply, and economic study of its use for any of the functions mentioned in comparison with a private industrial supply.

(8) Potential future requirements for expansion.

(9) Interrelation of various water requirements which may permit re-use and conservation of water.

(10) Modification of temperature, composition, or other qualities of water during plant use, which may affect its subsequent utility for other purposes, and the influence of these factors on the required treatment.

(11) Facilities for disposal of waste liquids, and jurisdiction of municipal, state, and federal authorities.

Reviewing briefly water specifications for process use, the authors point out that microorganisms are objectionable not only in food, beverage, and fermentation processes but also in many cases where they cause slime deposits in tanks, pipe lines, and manufacturing equipment. Iron and manganese in very small amounts cause discoloration and stains on products and processing equipment and can rarely be disregarded if they are present in appreciable amounts. Hardness increases the

consumption of soap and detergents in washing processes, and the calcium and magnesium may form insoluble precipitates with other processing chemicals.

For cooling water the chief considerations are said to be quantity, temperature, corrosiveness, and tendency to form deposits of mineral matter or organic slimes on the cooling surfaces. In boiler feedwater suspended solids must be absent, calcium and magnesium must be reduced as much as possible by softening or other means, and subsequent treatment in the boiler is often required to elevate the pH value and remove dissolved oxygen completely; concentration of sodium sulphate must also be present to inhibit caustic embrittlement. Organic matter, oil, and other extraneous matter must be absent.

The chief requirements for water for fire protection are a large potential supply and high pressure, and the water should be of a composition not deleterious to pipes and sprinkler lines. Potable and sanitary water supply is a matter of regulation by state and municipal health authorities, who have generally adopted the standards of the United States Public Health Service.

Treatment facilities for the preparation of process and boiler feedwater are discussed in general terms by the authors, who conclude their article with a brief consideration of liquid-waste disposal in plant layout. It is said that some undesirable constituents may be removed from liquid wastes by precipitation, coagulation, settling, and filtration, while others may be neutralized. In some cases there is no solution except the evaporation of water and the disposal of the waste material in concentrated form.

Keeping Moisture Out of Wood

MODERN PLASTICS

MEANS of treating the external surfaces of wood to reduce the swelling and shrinking caused by addition or loss of moisture in the cell structure are well known, but a treatment of the wood to cut down its affinity for moisture would permanently reduce this absorption and make possible cutting, nailing, and abrasion without loss of moisture-excluding efficiency. Such a treatment is under development at the Forest Products Laboratory of the Forest Service, U. S. Department of Agriculture, maintained at Madison, Wis., in cooperation with the University of Wisconsin, and is described in the April, 1937, issue of *Modern Plastics* by Alfred J. Stamm, senior chemist of the laboratory.

The wood is treated with a mixture of phenol and formaldehyde, together with a catalyst dissolved either in water or wood alcohol. In case the wood is green the treatment consists in soaking the wood in the solution at room temperature sufficiently long for the solution to diffuse into the entire fine structure of the wood, or, in the case of air-dried wood (4 to 15 per cent moisture), the diffusion part of the treatment can be advantageously preceded by an impregnation of the coarse capillary structure by placing the wood in a treating cylinder, evacuating, running the solution into the cylinder so as to completely immerse the wood, and then applying a pressure. This preliminary treatment is advantageous only in the event the lengths of the wood specimens in the fiber direction are not great and the species are among those easily treated, as the penetration of the solution is almost entirely in the fiber direction.

The phenol-formaldehyde solution has a great affinity for wood, as is shown by the fact that the wood swells more in it than in water alone. After standing in the solution a sufficient time to allow the resin-forming solution to diffuse into the cell walls, the wood is slowly dried so that further diffusion of the resin-forming materials into the cell walls accompanies the removal of solvent. The wood is then cured at about the boiling point of water. This heat-treatment causes the phenol and the formaldehyde to react to form a resin which is water-insoluble. The moisture-excluding efficiency obtained appears to be permanent and the wood can be cut and nailed without affecting the efficiency. The moisture-excluding efficiency increases with the concentration of phenol and formaldehyde used up to a maximum value of about 70 per cent for a single treatment. This efficiency can be somewhat increased by multiple treatments. The necessary amount of resin formed in the structure to give a moisture-excluding efficiency of 70 per cent will vary with the species and density of the wood from about 30 to 50 per cent of the weight of the wood. Efficiencies as high as 50 per cent have been obtained with as little as 15 per cent increase in the weight of the wood.

Not only are the swelling and shrinking of wood permanently reduced by this treatment but the mechanical properties are improved as well. The hardness and the compressive strength at the proportional limit perpendicular to the grain are increased considerably. Maple containing about 20 per cent of its weight of resin gave increases of over 50 per cent in each of these properties. Compressive strength parallel to the grain is increased somewhat less, and static bending properties and toughness are not affected.

Gluing tests showed that the treated wood can be satisfactorily glued with animal or casein glues. Excellent results were obtained with bakelite glues, using the hot-press, but not the cold-press, technique. Plywood glued with phenol-resin film or with casein glue was successfully treated with the synthetic resin without affecting the glue joints.

The present limitations of this process are the size of specimen and species that can be treated and the cost of treatment. Not all woods can be successfully treated because of the difficulty of getting the treating material distributed throughout the structure. A number of softwoods, the sapwood of a number of hardwoods, and the heartwood of the softer hardwoods have been successfully treated in specimens 14 to 4 by 1 in. in size. The largest specimen successfully treated to date is 30 in. long by 5 by 5 in. Larger specimens of the more readily treated species could undoubtedly be treated but the treatment would take prohibitive lengths of time.

On the basis of the complete treatment of the wood the cost would be about 40 cents per board foot. This figure is at least ten times the cost that could economically be added to millwork to minimize the dimension changes. Even at present costs the treatment might, however, be economically applied to such specialties as lithograph backings, shoe lasts, shuttles, wood bearings, small handles, and athletic goods.

As the cost of the treating process is mostly that of chemicals, there are possibilities of cutting costs by further reducing the amount of chemical needed. Although attempts are now being made to do this, theoretical considerations indicate that the probability of going far in this direction is small. In this age of synthetic resins it is quite possible that the cost of the raw materials will be further considerably reduced. Then, too, there is the possibility of treating only the outer $\frac{1}{16}$ to $\frac{1}{8}$ in. of large specimens. However, this eliminates the advantages of the process over other surface coatings.

The process is thus of practical value at the present time only in specialty fields. Research along these lines is being continued at the Forest Products Laboratory. With the aid of fundamental information and background gained to date, it is hoped that further efforts will yield results of more widespread use.

LETTERS AND COMMENT

Brief Articles of Current Interest, Discussion of Papers in Previous Issues

Railway Lubricants

To the Editor:

As stated by Mr. Hunter,[1] interchange of cars has made lubrication a problem common to all railroads. Standardization and adoption of a suitable grade of an all-year lubricating oil and a strict compliance with A.A.R. instructions regarding the periodical repacking and care of journal boxes and their contained parts by all railroads and private car owners are needed to reduce hotbox trouble. These cover preparation of packing, both new and renovated, the manner in which it should be placed in the journal boxes, and the quantity that should be used. They also set forth and describe conditions requiring renewal of journal bearings, wedges, and dust guards or collars. Since the adoption of these instructions, considerable progress has been made in reducing hotbox troubles. Further improvement, however, is possible and can be accomplished only by stricter compliance with instructions by all who are concerned.

Inexperienced journal-box packers, or those who have not been properly instructed, in most cases will put too much packing in the boxes, which prevents proper radiation and increases the menace of waste grabs. Frequent trimming and replacement of packing, especially in cold weather, is necessary to prevent hotboxes, and better results can thus be obtained than by the use of free oil only. To put free oil in a box does not do much, if any, good, if the packing is not in proper contact with the entire length of journal. In the protracted cold weather of last winter, we had to resort to extensive use of the packing iron before we had any success in reducing the hotbox trouble. To obtain best results in the application of free oil to journal boxes, it must be placed at the back of the box. This can be accomplished by inserting the spout of the oilcan in the box as far as possible and then placing oil along the up-turn side, if known, of the journal for its entire length. Placing oil in the front of the box does little, if any, good and is really a waste of both time and material.

S. D. Heyward.[2]

To the Editor:

Mr. Hunter's remarks concerning impurities entrained in superheated steam and their detrimental effect on proper cylinder lubrication should be of especial interest to all in any way responsible for locomotive operation and maintenance. These impurities result from the carry-over, into the superheater units, of water containing high concentrations of sediment, scale, and other impurities, which either are deposited there when the water is evaporated, or are swept along into the throttle and cylinders. This water carry-over can generally be divided into two classes:

(1) Occurring during short intervals of foaming, when almost solid water is lifted into the standpipe.

(2) Entrained during normal boiler performance, where from one to as high as five or ten per cent of moisture may be carried along in the steam, during periods of intensified steam liberation above the crown sheet, into the rather limited steam space of a modern locomotive boiler.

Foaming can be prevented only by proper instruction of train crews, water treatment, and blowdown, and considerable advance is continually being made in this. However, almost all the impurities carried into the steam by the second cause can be removed by installing an inexpensive, but efficient, form of moisture separator or steam drier, which is capable of returning over ninety per cent of the entrained water to the boiler, even when as much as twenty per cent of moisture is contained in the steam. Such a drier is of simple lightweight, construction, embodying no moving parts, and is located in the dome on top of the dry-pipe elbow. This device will not only help to solve the lubrication difficulties mentioned but also will result in decreased superheater maintenance and greater fuel economy, as realized from better lubrication and higher superheat, obtained in relieving the units of the burden of evaporating the moisture that would otherwise enter the elements. Thus, the separator will aid materially in removing the cause of poor cylinder lubrication rather than diminish the effect, thereby supplementing the work of the oil companies in developing higher-grade lubricants.

P. D. Blanchard.[3]

To the Editor:

Mr. Hunter stresses one point that we ought to support, the development of standard specifications for locomotive valve oil and greases. Practically no difference in their service requirements will be found on locomotives of various railroads, and having standard specifications developed and used by all railroads for these lubricants would certainly be of value.

His remarks on car lubrication are particularly interesting. Viscosity is the important feature of a car-oil specification and must be given first consideration. However, this oil should not have too high a pour point, and, while Mr. Hunter discounts the importance of pour point, the inference is that it should be around zero. I cannot reconcile the A.A.R. specification for new car oil which requires the maximum of 20 deg for summer oil and 0 for winter and all-year car oil and yet permits a pour point of 45 F for reclaimed oil. Using an oil that had a pour point as high as 45 deg would be impossible in this country in winter, unless the car oiler carried an electric heater.

W. A. Pownall.[4]

To the Editor:

Mr. Hunter lists among the major contributing factors for hot boxes: "Waste grab due to viscosity or tenacious character of the oil at low temperature." Mention should be made of waste grabs that occur with great frequency in summer. In most discussions of car-journal lubrication, below-zero temperatures are frequently stressed and, in the past few years, much consideration has

[1] "Railway Lubricants," by B. F. Hunter, Mechanical Engineering, April, 1937, pp. 235–238.

[2] Gulf, Colorado, & Santa Fe Railway Co.

[3] Western service manager, Superheater Company, Chicago, Ill. Mem. A.S.M.E.

[4] Mechanical engineer, Wabash Railway Company, Decatur, Ill.

been given to low pour point for car oils. Review of the records of hotbox failures on a great number of railroads shows that the best performance is in extremely cold weather. The greater number of hotboxes occurs in the so-called summer months. Many lubricating engineers and railroad officials seem to overlook this fact and confine their studies and observations to extremely low temperatures.

The purpose of summer and winter oils for car-journal lubrication, particularly in freight cars, is nullified because their use cannot be, and is not, controlled. Journal boxes are packed in the expectation that they will not require repacking for twelve or fifteen months. Therefore, cars that have journal boxes packed when summer oil is used must run through the winter and cars packed with winter oil must likewise run through the summer. Our records of hotboxes in winter do not indicate that cars of southern ownership, in which only one kind of oil is used, give any particular trouble. I am not particularly acquainted with performance records of northern owned cars operating in southern territory, but do not know that any complaint of their performance has been made.

The car-journal lubrication problem has many aspects and is the subject of considerable study. Excluding foreign matter from journal boxes, journal-bearing design, and methods for feeding oil to the journals are being studied. Of prime importance is development of an all-year car oil suitable for seasonal and climatic conditions, and education of car owners to its advantages.

G. W. DITMORE.[5]

TO THE EDITOR:

Standardization of lubricants used for railroad equipment is particularly necessary now that the introduction of air conditioning, Diesel equipment, roller bearings, and other new devices have so greatly increased the total number used on a single road. The author stresses the need for cooperation between the technical men on the railroads and the oil companies. We should go a step farther and bring the locomotive and equipment manufacturers into the conference.

Many of the devices for applying lubricants to locomotives are of such a nature that the best lubricants cannot always be applied. We should not only standardize on the best possible lubricant for each purpose but also the device for applying it should be brought to the maximum efficiency. The A.A.R. made a great step toward standardization when it appointed a director of research. It is to be hoped that Mr. Wallace will be able to coordinate the work that is being done both by the consumers and manufacturers of lubricants.

An all-year car oil must have sufficient film strength to carry the heaviest load in hot weather, which includes breaking in new axles and bearings, and also must not roll waste or cause waste grabs at temperatures as low as —50 F. Getting film strength for summer work was easy, but handling the winter situation and finding an oil with a high film strength which would function properly in extreme cold was more difficult. Much discussion has taken place as to the qualities in an oil which will cause waste-rolling. Some authors felt that pour test was the criterion; others that the extrapolated viscosities as calculated by the A.S.T.M. chart would indicate the waste-rolling tendencies of the oil. Experimental work has now shown that neither pour test nor calculated viscosity is a criterion. Some oils will roll waste at a calculated viscosity of 200,000, while others with a calculated viscosity of 1,000,000, will not. The author states that he hopes that oils of this character will be tried out next year. Several major roads in the coldest part of the Northwest have used all-year car oils for the last several years and, during the most severe weather conditions of last winter experienced practically no trouble from waste rolling, although using the same oil as in summer.

M. C. VAN GUNDY.[6]

TO THE EDITOR:

Discussion of locomotive lubrication must necessarily bring out the important item of driving-journal lubricants. At the inception of rail transportation, when a twenty-ton locomotive was considered a wonderful mechanical achievement, lubrication was easily accomplished by using waste packing in the driving-journal cellars with an occasional free oiling of the packing. Journal load was not a problem of efficient locomotive operation. The age of the small, light power was short lived. No sooner had the industrial world begun appreciating the fact that railroads were vital to the needs of the country, than the demand arose that larger, heavier, and faster locomotives be developed. In the course of this development, naturally journal loads became a salient point in efficient operation. The old method with waste packing was found to be inadequate for meeting the requirement for lubricating driving journals bearing tremendous weight, and it became obvious that, unless a better and more reliable method was forthcoming, the lubrication of locomotive driving journals would seriously retard rapid handling of traffic.

Developing a dependable and economical lubricant became necessary, and the response of the oil companies to this demand was the journal compound now universally used where fast, heavy locomotives are operating. This compound is a mechanical mixture, the chief constituent of which is cylinder stock, and, together with other ingredients, it forms a viscous bearing-lubricating substance that varies in hardness with the requirements imposed by climatic conditions, high speed, and heavy journal loads. Its nature is such that it readily attracts foreign matter, such as sand, boiler scale, and similar substances, to which it is exposed while a locomotive is being serviced in enginehouses and over pits where boilers are washed, sanders tested out, and driving cellars repacked. Careless and indifferent handling of journal compound will result in the hazard of bearings overheating and causing trouble on the road as well as the expense of turning and polishing the journals should they become cut by foreign matter in the journal compound.

After the compound is removed from the journal, it must be placed where it is not exposed to any foreign matter until it is transported to the reclaiming plant. If hand reclaiming of the compound is necessary, a substantial loss will occur because much of the compound to be reclaimed is cut away in removing this foreign matter.

Appreciating that savings could be made if the compound were handled cleanly and carefully while being placed in or removed from a driving-journal cellar, the Texas and Pacific Railway Company made exhaustive tests and careful study to develop an efficient method of handling and reclaiming. Finally through the efforts of the supervisors at Lancaster, Tex., shop, a machine was developed which not only separates foreign matter from used compound but also thoroughly mixes new compound before it is used. This consists primarily of a 12 × 18-in. brake cylinder securely mounted vertically on a heavily con-

[5] Master car builder, The Delaware and Hudson Railroad Corporation, Albany, N. Y.

[6] Technician, The Texas Company, Houston, Tex.

structed steel table. From nonpressure end of this brake cylinder, a piston with an auxiliary piston head secured to the bottom end protrudes. This head is six in. in diameter and fits snugly into steel cups, the bottoms of which are perforated with numerous $^3/_{64}$-in. holes.

When the compound is poured into molds at the refinery, the cylinder stock tends to coagulate in drops throughout the mass. To obtain uniform lubrication throughout the cake with which the driving cellar is to be packed, this coagulation must be broken up and a homogeneous mixture made of the mass. The pressure exerted to push new compound through the perforated cups of the machine effects an almost perfect distribution of the cylinder stock throughout the entire mass. Cleaning reclaimed compound is accomplished in the same manner. Foreign matter larger than $^3/_{64}$ in. remains in the cup which must be cleaned from time to time. The quantity of foreign matter that remains in the bottom of these cups after used compound has been passed through the perforations is surprising in spite of the most careful handling of the compound after it has been removed from the driving cellar.

After cleaning or mixing of the compound has been completed, the steel cups are removed and replaced by molds that conform approximately to the diameter of the journal for which the cake of grease is to be used and form a bevel on the bottom of the cake about 1 in. from each edge and extending the entire length. This beveling is designed to prevent the grease from being pressed against the sides of the cellar by the action of the follower plate after the compound has reached running temperature. The mold is filled with compound, the perforated grease container is placed on top, and pressure applied. When the molds are removed, the cakes of grease are ready for application to the journal, having been compressed into an almost solid mass with some of the material forced through the perforations in the container plate. This feature eliminates the necessity for priming the face of the plate that is exposed to the journal with grease before applying it in the cellar. After having been molded into shape, the cake is taken to the packing table for wrapping. Each cake is identified on the wrapper as either new or reclaimed compound.

All journal compound used on the system will be pressed into the perforated plates at Lancaster shop and distributed from there to various points on the system. When renewing compound in a driving-journal cellar becomes necessary, the mass will be removed with perforated plate and shipped to Lancaster for reclaiming, cleaning, and handling. Handling used journal compound effects savings of approximately fifty per cent and, in addition to the financial saving, the almost entire elimination of overheated driving journals has resulted. It is safe to say that the process is without doubt the most efficient known for handling the driving-journal compound as there is practically no waste whatever in this system of handling.

This method of handling journal compound has been in effect about three years, and records show that, aside from saving approximately 50 per cent on reclaimed compound, overheated driving journals are practically eliminated, and, should a driving journal become cut or overheated and interfere with operation, the trouble is known to be mechanical and not due to the lubricant.

J. D. CLYDE.[7]

TO THE EDITOR:

As a mechanical officer, who has received frequent demands for explanation of cause and responsibility for hot driving boxes, I have endeavored to develop an oil-lubricated journal box. In doing so, I realized the importance and necessity for some form of oil-sealing arrangement to be applied at both journal-box ends on inside journals, and on the hub side of outside journals to prevent endwise leakage with rotation of the journal. The next item of importance was some form of oil-conveying arrangement to be applied in the oil reservoir. This feature was worked out by the application of four ball bearings journaled in pairs and especially fitted in upright or protruding pedestals with coil springs under each effecting contact with the journal and rotating with it. The driving box was designed so that the oil reservoir came in direct contact with the crown bearing and was held in position by supports anchored to the leg of the box and adjusted taut with the crown bearing. Each end of the reservoir is equipped with a recess, and each end of the crown bearing is grooved in perfect alignment with those in the end of the reservoir. In this groove, a three-section oil-retaining ring moves, is held in position on the journal by a $^3/_{16}$-in. garter spring, and rotates with it. Its duty is collecting oil moving in an endwise direction and depositing it in the oil reservoir, the oil-retaining ring moving on the journal when the driving box is in lateral motion.

Two driving boxes of this design were applied to one of our Pacific-type passenger locomotives with an axle load of 58,700 lb, a journal diameter of $10^1/_2$ in. and a length of 13 in. on May 17, 1933, and were in continuous service until June 13, 1934, with a mileage record of 72,472 miles. When this locomotive was shopped in June, 1934, the trailer wheels were similarly equipped. Since placed in service on Oct. 31, 1934, this locomotive had run 63,680 miles on May 1, 1936, without any difficulty or delay of any kind and without the necessity of taking up lateral wear.

J. N. BLUE.[8]

Flow in Fan Volutes

TO THE EDITOR:

In connection with the recent paper by Binder and Knapp,[9] the following summary of work on experimental verification of basic assumptions in the design of volutes of centrifugal fans, by V. Polikovsky and G. Abramovitch, engineers of the Central Aero Hydrodynamical Institute, U.S.S.R., should be of interest:

An experimental verification was obtained of the basic assumptions usually made in the design of a volute casing for a centrifugal fan. The checking consisted in the measurement of velocity distributions in several sections of two volute casings. Each casing was of constant breadth (along a line parallel to the axis of rotation).

For each fan, at each section the velocity measurements were made at different capacities or discharges. The range was from the lowest to the highest fan capacity. An analysis of the velocity measurements led to the following conclusions:

1 At normal fan discharge, corresponding to the case when the measured discharge is almost equal to the discharge as calculated from theoretical considerations of the casing contours, a symmetrical velocity distribution at each casing section was found, as well as a uniform velocity distribution around the circumference or periphery of the runner.

At normal fan capacity, the discharge of air into the casing starts where the involute curve extended intersects the periphery of the runner.

[7] General locomotive foreman, The Texas & Pacific Railway Company, Fort Worth, Tex.

[8] Master mechanic, The Texas & Pacific Railway Company, Big Spring, Tex.

[9] "Experimental Determinations of the Flow Characteristics in the Volutes of Centrifugal Pumps," by R. C. Binder and R. T. Knapp, Trans. A.S.M.E., vol. 58, 1936, pp. 649–661.

2 At fan discharges below normal, only a part of the runner does useful work. There are two possibilities: (*a*) Part of the runner periphery is discharging no air into the volute or casing; or (*b*) at some part of the runner periphery there is a reverse flow of air, that is, air flows toward the axis of rotation.

In that part of the wheel periphery which is doing useful work (in that area where the air is being delivered *to* the casing), the specific capacity, or volumetric efficiency, is the same as in the case of a fan operating at normal capacity.

As the fan capacity is lowered, the useful area of discharge is reduced, while the efficiency of the remaining useful discharge is the same as at normal capacity.

3 At capacities below normal, there is a closed circulation of air in the casing, and the circulation increases as the fan discharge decreases.

4 At capacities above normal, most of the runner continues to operate as efficiently as the whole runner does at normal capacity. The increase in capacity is obtained chiefly by an increase in work at the volute tongue, that is, in that region where the casing meets the discharge nozzle.

5 The losses in the casing are not friction losses.

6 In each of the different sections of the casing, the measured tangential-velocity components did not follow the law of constant angular momentum. If it is assumed that a "free vortex" exists in the volute, the angular momentum will be constant, and the product RC will be constant, where R is the radius to some point in the volute, and C is the tangential velocity at that point. A "free vortex" then states that the tangential velocity should decrease as the radius is increased. Instead of this, the measurements showed an almost constant value for the tangential-velocity component.

From the analysis of these velocity measurements, it is possible to make certain conclusions regarding the design of volute casings. Some of the factors to be brought out are (*a*) the desirability of increasing the periphery of the casing with a corresponding decrease in the angle of divergence, and (*b*) the effect of increasing or decreasing the capacity on the head losses in volute casings.

However, the main value of this investigation does not lie in these practical recommendations. The main value lies in giving a general idea of the flow conditions in a volute casing, and these measured results show a rather poor agreement with the assumptions usually made, especially for discharges differing considerably from normal capacities. These experiments should also aid in predicting the general effect (or trend) of changing some feature of a volute design.

The complete effect of a new volute-casing design will be possible only after a thorough study has been made of the internal flow conditions through the whole fan. This can be done by using both visual and quantitative experimental methods.

A. NEKRASSOV.[10]

Computation of Pipe-Line Discharge

TO THE EDITOR:

Trial-and-error and graphical-interpolation methods for computing pipe-line discharge from friction loss were never necessary. The scheme presented by Ed S. Smith, Jr.,[11] is ingenious but unnecessarily complicated.

Early workers in the field of pipe flow appreciated that flux and pressure gradient are two sides of the same coin, since they used for water both

$$S = C\sqrt{DG/E} \quad \ldots\ldots [1]$$

and

$$G = fES^2/D \quad \ldots\ldots [2]$$

in which, S is average speed, or flux over area; D, pipe diameter; G, pressure gradient; E, density; C of Equation [1] is a flow coefficient; and f of Equation [2] a friction factor.

It was soon found that C and f are not constant, and many systems of estimating them grew up. Reynolds, however, introduced a unifying concept in the form

$$D^3EG/V^2 = A[DES/V]^n \quad \ldots [3]$$

in which V is the viscosity, and A and n are constants.

Solving Equation [3] for G and then comparing the solution with Equation [2] is simple; the result is

$$G = A\left(\frac{DES}{V}\right)^{n-2}\frac{ES^2}{D} \quad \ldots [4]$$

and

$$f = A\left(\frac{DES}{V}\right)^{n-2} \quad \ldots\ldots [5]$$

Experimental evidence available before 1914 supported Equation [5]; in that year, Stanton and Pannell showed that Equation [5] did not hold throughout the range of their experiments.

Although Equation [5] represents experiment only for values of DES/V, since called the Reynolds number, of less than 100,000, a generalized form

$$f = \text{function of}\left(\frac{DES}{V}\right) \quad \ldots [6]$$

was found to hold, and the plot of friction factor against Reynolds' number has become familiar to most engineers.

If nothing other than the friction factor-Reynolds' number plot were available, trial-and-error or graphical-interpolation would be necessary to compute flux from pressure gradient. But Equation [3] can be generalized as well as Equation [5], and it can be written

$$\frac{DES}{V} = \text{function of}\left(\frac{D^3EG}{V^2}\right) \quad \ldots [7]$$

Equation [7] can be solved for S, and the solution compared with Equation [1], leading to

$$C = \text{function of}\left(\frac{D^3EG}{V^2}\right) \quad \ldots [8]$$

With such a plot available, direct computation of pipe-line discharge can be made very simply. In 1932 Drew, Koo, and McAdams[12] published a plot of Equation [8] and mentioned that it could be used for eliminating trial-and-error methods in computing flux from pressure gradient, although they did not stress either the plot or its use. The writer[13] has shown how Equation [8] results from dimensional reasoning applied to the problem of determining the flow rate from the pressure gradient and has emphasized that plots can be discarded, since a simple formula is obtained

$$M = 1.11(D^5EG)^{1/2} \times \log_{10}\left(\frac{D^3EG}{V^2} - 0.50\right) \quad \ldots [9]$$

in which M is the mass flow rate. Equation [9] must be used with consistent units, but it may be transformed with change of constants for use with any set of units and solved directly for flux or average speed. For example, oil-line flow rates can be computed with

$$B = 4.06\left(\frac{d^5I}{s}\right)^{1/2} \times \log_{10}\left(\frac{d^3sI}{Z^2} + 4.35\right) \quad \ldots [10]$$

[10] Vice-President, Central Aero-Hydrodynamical Institute, Moscow, U.S.S.R.

[11] "Direct Computation of Pipe-Line Discharge," by Ed S. Smith, Jr., MECHANICAL ENGINEERING, May, 1937, p. 375.

[12] "Friction Factor for Clean Round Pipes," by T. B. Drew, E. C. Koo, and W. H. McAdams, Transactions of American Institute of Chemical Engineers, vol. 28, 1932, pp. 56–72.

[13] "Fluid Flow in Clean, Round, Straight Pipe," part 1, by B. Miller, Transactions of American Institute of Chemical Engineers, vol. 32, 1936, pp. 1–6.

in which B denotes flux, bbl per day; d, pipe diameter, in.; I, pressure gradient, lb per sq in. per mile; s, oil specific gravity (water = 1); and Z, oil viscosity, centipoises.

BENJAMIN MILLER.[14]

TO THE EDITOR:

Mr. Miller's comments on Ed S. Smith, Jr.'s, letter, "Direct Computation of Pipe-Line Discharge," can be proved not to comprehend the whole range of pipe friction. Formulation of the friction formulas, as outlined by Mr. Miller, has been done many times by Stanton and Pannell, Lees, von Kármán, and others. However, I agree that, for the present at least, Mr. Smith's use of graph methods is more desirable for the general practitioner who has to deal with more than one kind of pipe.

The paper by Dr. Emory Kemler[15] and my own,[16] which was a sequel to his work, clearly show that friction can be formulated closely for each roughness of pipe and for limited ranges of Reynolds' number, but in no case, including the smooth pipe, is a single formulation apt to be exact. Of course, the smooth-pipe friction line, first accurately developed by Stanton and Pannell and later checked by Saph and Schoder and Jakob by other experimental work, has been represented closely in various formulations, but unfortunately this line does not represent all the pipes. In fact, it represents relatively few of them. Probably, the reason Mr. Miller finds formulation simpler than graphical plotting is that he appears to be working chiefly in oil pipe lines which are, as a rule, 8 in. in diameter or larger, or perhaps in natural-gas lines which are much larger again, and all these pipes, ordinarily built of steel, fall practically in the smooth-pipe class. However, those interested in industrial work may be dealing with pipe lines down to $^1/_8$ in. inside diameter, may be working with small-size galvanized pipe, or, perhaps, figuring loss in riveted flues or brick ducts.

From inspection of the curves in my paper,[16] it is obvious that a single formulation cannot cover this ground. For example, we have successfully applied the charts in my paper to calculations of flow in an oil system of an automobile engine, in which none of the pipes is larger than $^3/_8$ in. inside diameter, and the flow changes from turbulent to viscous when it finally reaches the bearings. Results computed by graphical methods checked within 10 per cent of test results, which under the circumstances may be considered very good. For such purposes, Mr. Miller's single formulation based on smooth pipe would, of course, be without value. The pipe liner, either in oil or natural gas, can ordinarily use this formulation conveniently but, for most of the other computations, including those involved in power stations or a chemical establishment, the graphical method is still the most useful and convenient.

R. J. S. PIGOTT.[17]

TO THE EDITOR:

Are not trial-and-error and graphical interpolation methods a lesser evil than the inflexible and approximate formulas, whether exponential or logarithmic, supported by B. Miller? The latter alternative was not considered even noteworthy by the writer, whose occasional use of such formulas from 1920 on has led him to adopt graphical methods completely as uniquely covering the entire field of flow with a truly simple square, or square-root, formula and a simple graph.

There is a serious question as to the wisdom of discarding a plot in favor of even a simple formula, i.e., one not involving high and fractional powers and logarithmic terms, since the Reynolds-number plot takes proper account of both turbulent and viscous laminar flows and their intervening discontinuity, while a formula is good only for turbulent flow and must be bolstered up by a separate calculation of the Reynolds number, using either the actual or "theoretical" velocity, to tell whether such formula or Poiseuille's formula applies. It seems far less complicated to use a graph and a simple universal formula than to require several formulas and then have to determine which formula applies.

The fact that Mr. Miller has called the attention of mechanical engineers to references from the field of chemical engineering amply justifies the writer's publication of his plot that permits direct computation of either discharge or pipe friction as desired. An even superior skewed graph has appeared recently.[18] Data conventionally plotted on this graph can be used to obtain directly the flow or friction respectively using the skewed or rectangular ordinates, an advantage not found in either of the references of Miller.

The operator of Miller's Equation [8] is to be found in the *Instruments* reference in the writer's earlier letter. Incidentally, Miller's comment that the authors of his first reference "did not stress either the plot or its use" is not supported by the quotation concluding its context:

"Since the expression for the abscissa does not contain the velocity, this type of chart permits the solution, without trial and error, of the flow problem which requires the rate of discharge through a pipe of known diameter with a given pressure drop."

ED S. SMITH, JR.[19]

[14] Cities Service Company, Inc., New York, N. Y.

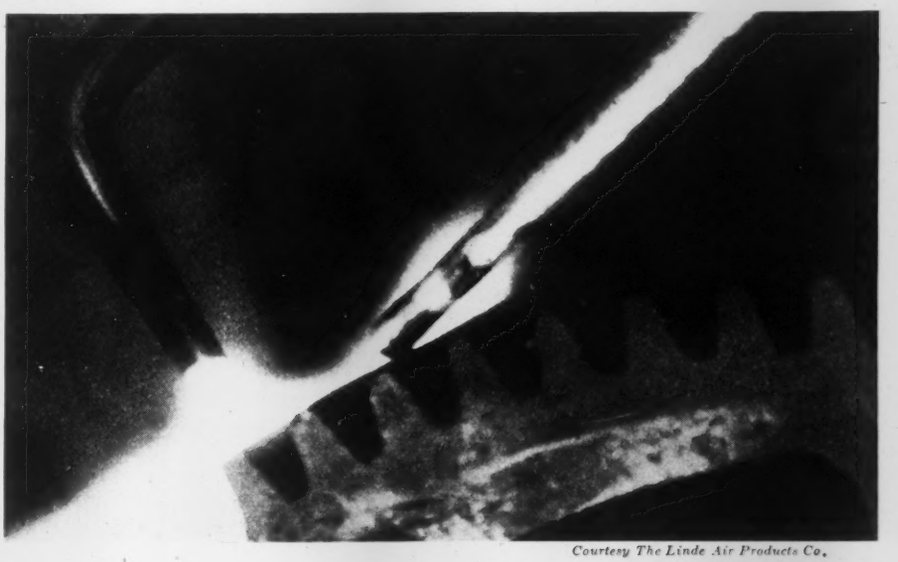
[15] "A Study of the Data on the Flow of Fluids in Pipes," by Emory Kemler, Trans. A.S.M.E., vol. 55, 1933, paper HYD-55-2.

[16] "The Flow of Fluids in Closed Conduits," by R. J. S. Pigott, MECHANICAL ENGINEERING, August, 1933, pp. 497–501 and 515.

[17] Gulf Research & Development Co., Pittsburgh, Pa. Mem. A.S.M.E.

[18] "Fluid Measurement and Control," by Ed S. Smith, Jr., *Chem. & Met. Engg.*, vol. 44, no. 5, May, 1937, pp. 278–282 (see Fig. 5 on p. 280.)

[19] Hydraulic engineer, C. J. Tagliabue Mfg. Co., Brooklyn, N. Y. Mem. A.S.M.E.



Courtesy The Linde Air Products Co.

REVIEWS OF BOOKS

And Notes on Books Received in the Engineering Societies Library

Invention and the Law

INVENTION AND THE LAW. By Harry Aubrey Toulmin, Jr., Prentice-Hall, Inc., New York, 1936. Cloth 6 × 9 in., 399 pp., $5.

REVIEWED BY H. H. SNELLING[1]

WHILE the author hopes that his "volume will be of service to the bench and bar and to that portion of the public which has to deal with patentable invention" it is feared no ordinary mechanical engineer could safely follow many of the various statements laid down because the author has expressed these mere tendencies as if they were rules of law. Practically all patent lawyers would naturally take these expressions in exactly the manner intended but an engineer would surely be confused to read on page 263: "Change in proportion does not constitute invention, because a change in proportions is primarily a matter of mechanical skill or engineering talent," for the true rule is as given on a distant page: "Change of Proportions. Proportions and their selection may constitute invention where the difference between failure and success lies in the proportion selected."

Likewise, the engineer would be led astray by the sentence on page 76: "The law encourages sufficient delay on the part of the inventor, before he makes his disclosure, for him to determine that his invention is workable." Every patent lawyer knows that this frequently repeated thought is not really true because the burden of proof of showing that a device will work is rarely placed on the inventor, but on the contrary, both in the Patent Office and in the courts only the most convincing argument that the device will not work will be accepted from an antagonist.

It is also to be regretted that some decisions which are never followed on certain points should be given undue prominence; for example, nine of the ten federal circuit courts of appeals have denied the strict rule of Pickering vs. McCullough, 104 U. S. 310, "In a patentable combination of old elements, all the constituents must so enter into it as that each qualifies every other;" yet this particular wording is quoted three times, on pages 103, 106, and 253, without a hint that the rule laid down is no longer good law.

At the opening of chapter 4 we are much disappointed to have the first citation not only useless, since it conveys no information except that a patent was held void for lack of invention without telling why, but inaccurate as well for the alleged citation is but a syllabus and is not within the decision. How much better it would have been to cite the actual words: "if patentability existed at all, it must depend upon the truss rod support or the adjustable stay rods . . . To provide such supports would be but a step obvious to any skilled mechanic." It would also have been better to have omitted reference to the earlier patent which was merely held not infringed.

The first chapter gives the "Background of Invention" and it is felt sure this chapter will be found both interesting and informative. The second chapter, "Characteristics of Invention," introduces the specific subject and deals with essential questions of invention. It is disconcerting to read that as soon as an invention is reduced to practice it "has all the attributes of a property right" (page 89), because this reviewer has very different ideas on the subject which seem well-supported by the Supreme Court citation on the very next page: "Until the *patent* is *issued* there is no property right in it" (the invention) . . . "Until then there is no power over its use, which is one of the elements of a right of property in anything capable of ownership."

The third and fourth chapters, each nearly a third of the book, treat "What Is Invention" and "What Is Not Invention," giving well-selected excerpts from decisions of appellate courts supplemented by helpful comments of the author. The fifth chapter "The British Rule," like the bibliography, would hardly be of value to an engineer, but would be of interest to the bench and bar.

The book is well-printed, nicely bound, and most moderate in price, hence it will be found in the library of most patent lawyers who will undoubtedly find it a convenient manual for their use when "determining the various perplexing problems concerning what is and what is not patentable invention."

[1] Snelling & Hendricks, Washington, D. C. Mem. A.S.M.E.

Marketing

OUTLINES OF MARKETING. By H. E. Agnew, R. B. Jenkins, and J. C. Drury. McGraw-Hill Book Co., Inc., New York, N. Y., 1936. Cloth, 6 × 9 in., 324 pp., $2.75.

ESSENTIALS OF DISTRIBUTION. By P. D. Converse. Prentice-Hall, Inc., New York, N. Y., 1936. Cloth, 6 × 8 in., 588 pp., $2.80.

TRAFFIC AND TRADE. By J. Paver and M. McClintock. McGraw-Hill Book Co., Inc., New York, N. Y., 1935. Cloth, 9 × 12 in., 137 pp., $4.50.

ADVERTISING: THEORY AND PRACTICE. By C. H. Sandage. Business Publications, Inc., Chicago, Ill., 1936. Cloth, 6 × 9 in., 618 pp., $4.

ADVERTISING COPY. By G. B. Hotchkiss. Harper and Bros., New York, N. Y., 1936. Cloth, 6 × 8½ in., 432 pp., $4.

FUNDAMENTALS OF INDUSTRIAL MARKETING. By R. F. Elder. McGraw-Hill Book Co., Inc., New York, N. Y., 1935. Cloth, 6 × 9 in., 317 pp., $3.

MARKETING INDUSTRIAL EQUIPMENT. By B. Lester. McGraw-Hill Book Co., Inc., New York, N. Y., 1935. Cloth, 6 × 9 in., 307 pp., $3.50.

PACKAGING, PACKING, AND SHIPPING. Edited by J. O. Rice. American Management Association, New York, N. Y., 1936. Cloth, 8½ × 11½ in., 237 pp., $7.50.

REVIEWED BY E. DILLON SMITH[2]

ONE of the greatest problems of modern industry is not how to make people buy what has already been made but how to manufacture what people will want to buy. For the manufacturer, this means elimination of indiscriminate mass output of products that differ from the numerous others on the market only in size, shape, or color of package or in numerous other details. The prime requisite of the business that desires to progress and grow in this modern era is a survey of marketing both on the economic and mental side.

"Marketing consists of those business activities involved in the flow of goods and services from the point of production to the point of consumption." Agnew, Jenkins, and Drury present this

[2] Professor of mechanical engineering, College of the City of New York, N. Y. Also Economic adviser to A.S.M.E. Management Division. Jun. A.S.M.E.

subject from the consumers' economic viewpoint with a slight description of the psychological factors that make consumers buy; the first attempt of the economist to admit the psychological approach to distribution is given in this work, but, unfortunately, without so identifying and fully crediting the approach. Other works of this series have also confined their attention mainly to the economic viewpoint instead of including the behaviorist's mental analysis. This simply means that economics of price is secondary to quality and artistic acceptance of the product, provided the price is within the price class. Agnew covers the fundamentals of the subject with a wealth of visual, factual, and descriptive material.

For the engineer who wishes to begin the study of distribution and for those engaged in business who want a comprehensive view of the field of distribution, Converse has condensed and simplified the principles of market distribution into its essential elements. This work treats distribution costs, distribution functions, distribution of selected commodities, operations of various types of middlemen, and principles of merchandising, salesmanship, sales management, and advertising. Each subject is discussed briefly.

An introduction to the analysis of the relationship between the daily habitual movement of people and their trade activities in markets is given by Paver and McClintock. Although this work is of great interest to an understanding of buying power and traffic in regard to trade problems, it is essentially academic in its treatment and lacks organization in its presentation of the wealth of information collected. It will be of interest only to those concerned with traffic control and some specialized phases of distribution.

Once the product is satisfactory to the producer, its advertisement is essential to sales. Outstanding in the treatment of the theory and practice of advertising is Sandage's book. He has taken the viewpoint of a few progressive advertising agencies who regard advertisements essentially as units rather than as a collection of separate elements. When the advertisement has been designed and set up, it ceases to be a collection of parts and becomes an entity with a specific purpose. Its effectiveness can be measured only in what it does as a whole, not how good its parts are. This is the concern of Hotchkiss' able and lucid treatment. The sales resulting from an advertisement are due to all the elements in it, all acting together as a unit. Thus, regarding advertisements as entities will greatly simplify our thinking. These works look toward the psychology of advertising and of individual differences as a means that might measure the relative effectivensss of any specific copy.

Distribution of capital goods is the concern of the books by Elder and Lester. These two books can be discussed together; however, the former is slightly more academic than the latter, if that distinction can be made. Lester's book is the result of his experience with Westinghouse and the University of Pittsburgh. Principles of distributing durable goods of an engineering nature from the manufacturer to the ultimate user are presented in elaborate detail that will be easily grasped by the engineer concerned with this problem. For the first time a logical sequence of thought and action in an analysis of the product to be sold, market to be met, and methods and organization required in the distribution of durable goods has been presented in sharp relief in both of these industrial-marketing books. The reader will have to go to the books themselves to appreciate their learning, their acute reasoning, and their incisive comment.

Just five short years ago, the American Management Association sponsored the art and science of container design as it affects merchandising, namely, packaging. Timely and highly appropriate as the most significant publication in management this year is this collection of 42 worth-while articles that have withstood the test of time and were presented at six annual conferences. Over fourscore illustrations of packages winning the Association's competition for distinctive merit in packaging are analyzed. Irwin D. Wolf trophy winners for 1932–1936, together with honorable mentions, are not to be missed by any industrialist. The most cogent reason why one must study this trenchant publication is that, once the product leaves the factory, it reaches the consumer at the critical moment—the point of sale—where its fate hinges largely on the interrelationship of three factors; the psychological behavior of the customer, a salesperson considerably less expert than the store buyer who was psychologically motivated to buy the product, and the package. Properly used, ideas presented in this masterpiece will reduce marketing costs and increase profits; this is the theme of all properly conducted phases and aspects of marketing research.

Books Received in Library

ELECTRIC POWER DEVELOPMENT in the U.S.S.R., edited by U.S.S.R. Committee for International Scientific and Technical Conferences, Krzizhanovsky Power Institute of the Academy of Sciences of the U.S.S.R. Lawrence & Wishart, Ltd., London, 1936. Cloth, 6 × 9 in., 496 pp., illus., diagrams, charts, maps, tables, $3. This volume was prepared for the Third World Power Conference in Washington by the members of the scientific staff of the Krzizhanovsky Power Institute of the Academy of Sciences of the U.S.S.R. It is an exposition of the principal technical and economic problems of electrical development in the Soviet Union, and of the plans for meeting them. Much information is given upon the engineering principles applied in the design of steam and hydraulic electric plants, transmission systems, etc.

ENGINEERING THERMODYNAMICS. By N. C. Ebaugh. D. Van Nostrand Co., New York, 1937. Cloth, 6 × 9 in., 208 pp., illus., diagrams, charts, tables, $2.85. A textbook covering the elementary essentials of the science of thermodynamics as it applies to modern industry. The various chapters treat fluid states, energy equations, gas and vapor properties and mixtures, vapor power, internal-combustion and refrigeration cycles, entropy, and gas compression. An appendix contains answers to chapter exercises, steam tables, and a psychrometric chart.

FARM MACHINERY AND EQUIPMENT. By H. P. Smith. Second edition. McGraw-Hill Book Co., New York and London, 1937. Cloth, 6 × 9 in., 460 pp., illus., diagrams, charts, tables, $3.25. This edition is greatly revised as a result of the rapid progress in the mechanization of agriculture. A brief discussion of fundamental mechanics and materials of construction is followed by a description of farm-machine elements. The main part of the book covers the design, construction, operation, and efficiency of various types of farm machinery, from plows to mechanical cotton harvesters and terracing machinery.

FIRST COURSE IN STATISTICAL METHOD. By G. I. Gavett. Second edition. McGraw-Hill Book Co., New York and London, 1937. Cloth, 6 × 9 in., 400 pp., diagrams, charts, tables, $3.50. A textbook for use as a foundation course in "Statistical Method" for all the various fields in which the mathematical representation of facts is desirable. Only fundamental material is considered from which a student can proceed in any desired direction. Several appendixes present simple, brief explanations of such basic mathematical manipulations as are necessary to follow the text.

FLUID MECHANICS. By R. A. Dodge and M. J. Thompson. McGraw-Hill Book Co., New York and London, 1937. Cloth, 6 × 9 in., 495 pp., illus., diagrams, charts, tables, $4. An elementary textbook covering the field of fluid mechanics. Planned and developed in accordance with recent trends in engineering education, the book offers a treatment of the fundamental principles common to hydrostatics, hydraulics, hydromechanics, and aerodynamics. There are many illustrative examples and problems.

FREEHAND AND PERSPECTIVE DRAWING. By H. E. Everett and W. H. Lawrence. American Technical Society, Chicago, 1937. Cloth, 6 × 9 in., 72 pp., illus, diagrams, $1.50. This book is divided into two sections. The one on freehand drawing covers materials and tools with simple exercises and plates to be copied illustrating their use. The section on perspective covers rules, planes of projection, and various perspective diagrams including examples and problems.

GEAR CUTTING PRACTICE. By F. H. Colvin and F. A. Stanley. McGraw-Hill Book Co., New York and London, 1937. Cloth, 6 × 9 in., 344 pp., illus., diagrams, charts, tables, $3. A practical manual of exact, descriptive data on all aspects of gear-cutting practice. Shows how to handle all kinds of gear jobs by modern methods. Describes spur gears and circular cutters, helical and herringbone gears, bevel gears, worms and worm gears, and internal gears; gives all the essential information on cutting, finishing, use of coolants and lubricants, burnishing, shaving, lapping, grinding, etc.

GRAY CAST IRON, General Manufacture, Structural Metallurgy and Engineering and Physical Properties. By J. W. Bolton. Penton Publishing Co., Cleveland, Ohio, 1937. Cloth, 6 × 9 in., 383 pp., illus., diagrams, charts, tables, $5.15. Intended to present, to both the nontechnically trained reader and the research worker, the basic metallurgical principles involved in the manufacture of gray iron to modern engineering specifications. The material covers all pertinent subjects from raw materials to corrosion problems. Bibliographical references are scattered through the text.

GREAT BRITAIN, DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH. Report for 1935–1936. His Majesty's Stationery Office, London, 1937. Paper, 6 × 10 in., 195 pp., tables (obtainable from British Library of Information, 270 Madison Ave., New York, $0.95). This report affords a comprehensive summary of the work carried on during the year in the various establishments of the department. Each report includes a list of articles published as a result of the investigations. A summary of the work of other British research institutions is also presented, so that the book forms a convenient review of all scientific and industrial research in Great Britain. Useful appendixes give the membership of the department committees, the addresses of its establishments, the addresses and directors of other research institutions, of publications by the recipients of grants for research, and of the departmental publications.

HOW TO BE A GOOD FOREMAN. By C. Reitell. Ronald Press Co., New York, 1937. Cloth, 5 × 8 in., 186 pp., diagrams, charts, tables, $1.50. The material in this book is divided into three sections which cover the essentials that go to make up good foremen: mastery of the human elements (leadership), a grasp of technical requirements (technical skill), and knowledge and use of costs and budgetary controls (business ability).

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS, International Congress, London, April 19–24, 1937. Advance Proofs of Papers, Groups A-D. International Association for Testing Materials, 28 Victoria St., London, S.W.1, 1937. Group A, 174 pp.; Group B, 159 pp.; Group C, 106 pp.; Group D, 71 pp. Paper, 7 × 11 in., illus., diagrams, charts, tables. These pamphlets contain advance proofs of the papers submitted at the London Congress of the Association in April, 1937. The subjects discussed include the effect of temperature upon the behavior of metals, the progress of metallography, light metals and their alloys, the workability and wear of metals, cement and reinforced concrete, natural stone, ceramic materials, textiles, wood cellulose, timber preservation, the aging of organic materials, colors and varnishes, the relation between the results of laboratory tests and behavior in use, the bearing of recent advances in physics and chemistry on the knowledge of materials, and the properties of materials for the thermal and acoustic insulation of buildings.

INTRODUCTION TO MODERN THERMODYNAMICAL PRINCIPLES. By A. R. Ubbelohde. Clarendon Press, Oxford, England: Oxford University Press, New York, 1937. Cloth, 6 × 9 in., 131 pp., diagrams, tables, $3. This book provides an introduction to the principles on which modern thermodynamics is based, centering round the use and evaluation of thermodynamic functions such as entropy and free energy. Special methods and advanced applications in the modern field are considered.

JOURNAL OF THE ROYAL TECHNICAL COLLEGE. Vol. 4, Part 1, Jan., 1937. Royal Technical College, Glasgow. Paper, 7 × 10 in., 212 pp., illus., diagrams, charts, tables, 10s 6d. This number of the research bulletin of the College contains a number of papers of engineering interest. Among them are: Tension and notched-bar tests on an alloy steel; liquid films between seized surfaces; viscous flow under surface tension forces. The binary system FeO-Al_2O_3; the identification of nonmetallic inclusions in steel; axial bending stresses in thin cylindrical shells with flat and spherical ends; model split flap airfoil—comparison with full-scale; principle of change speed in epicyclic gearing; stress distribution in irregular sections using photoelastic models; the sensitivity of the Schering bridge network; the commutation period in grid-controlled mercury-arc rectifiers; experiments on the wetting of mine dusts; regulators in mine ventilation; effect of length on the effective horsepower of ships.

KERBSPANNUNGSLEHRE, Grundlagen für genaue Spannungsrechnung. By H. Neuber. Julius Springer, Berlin, 1937. Paper, 6 × 10 in., 160 pp., diagrams, charts, tables, 15 rm. This publication concerning a "notch-stress-gage" is devoted to the problem of precise determination of strength and stresses in structural parts.

KORROSION VI. Bericht über die Korrosionstagung 1936 am 22 Oktober, 1936 Köln. V.D.I. Verlag, Berlin, 1937. Paper, 6 × 8 in., 61 pp., illus., diagrams, 5 rm. The proceedings of the 1936 conference on corrosion, organized by various German engineering and chemical societies, are presented. Grouped around the central theme, the prevention of corrosion by structural precautions, are seven papers, discussing possible precautions in railroad equipment, automotive vehicles, chemical apparatus, gas mains, rope, steel structures, and ships.

LAW FOR ENGINEERS AND ARCHITECTS. By L. P. Simpson and E. R. Dillavou. Second edition. West Publishing Co., St. Paul, Minn., 1937. Cloth, 6 × 9 in., 692 pp., $4.50. Text and case material stating and illustrating the fundamental principles of law in those branches which bear most directly upon the engineering profession. In particular, the law of contracts has been treated at great length. Standard contract forms are illustrated in an appendix.

MAN IN A CHEMICAL WORLD, the Service of Chemical Industry. By A. C. Morrison. Chas. Scribner's Sons, New York and London, 1937. Cloth, 7 × 9 in., 292 pp., illus., diagrams, charts, tables, $3. An account of the activities of chemical industry in converting the discoveries of science into day-by-day necessities. Various fields of activity are considered and the part played by chemistry in their development is demonstrated. Betterment of existing materials, creation of new ones, and the replacement of scarce or waning natural resources with synthetic substitutes are examples.

MITTEILUNGEN AUS DEN FORSCHUNGSANSTALTEN GHH-KONZERN, Bd. 5, Heft 3, April, 1937. pp. 53–74. V.D.I. Verlag, Berlin. Paper, 8 × 12 in., diagrams, charts, tables, 2 rm. Current number of the publication of a German research organization, containing two articles, one on the packing density of fine coal, and the other on a new precision regulator with a high speed range.

MOTOR AND CONTROL APPLICATIONS. By G. H. Hall. McGraw-Hill Book Co., New York, 1937. Cloth, 6 × 9 in., 259 pp., illus., diagrams, charts, tables, $3. Information for the machine designer, to assist in the selection of electrical equipment. The first chapter takes up briefly the determination of machine requirements. The succeeding chapters present the characteristics of various types of motors and the performances that may be secured from them by the selection of suitable control. The final chapter presents data and dimensions of motors as standardized by the National Electrical Manufacturers Association.

NATIONAL PHYSICAL LABORATORY REPORT for the Year 1936. Great Britain, Department of Scientific and Industrial Research. His Majesty's Stationery Office, London, 1937. Paper, 6 × 10 in., 144 pp., tables. (Obtainable from British Library of Information, 270 Madison Ave., New York, $0.80.) Contains a résumé of the research work done in 1936 in the following departments: Physics, electricity, radio, metrology, engineering, metallurgy, aerodynamics, and the William Froude laboratory. Also included is general information as to the staff, buildings, etc., and a list of reports and papers published in 1936.

PASCAL, the Life of Genius. By M. Bishop. Reynal & Hitchcock, New York, 1936. Cloth, 6 × 10 in., 398 pp., illus., diagrams, cloth, $3.50. A scholarly, annotated biography of a man whose life had many interests and contacts. The author has departed from the ordinary chronological treatment, except for certain general information, and has divided his material according to the various phases of Pascal's activities. An intelligent handling of a complex personality.

REFRIGERATION ENGINEERING. By H. J. Macintire. John Wiley & Sons, New York, 1937. Cloth, 6 × 9 in., 415 pp., illus., diagrams, charts, tables, $4.50. The expanded

field of refrigeration engineering has been treated here from the fundamentals to the numerous special adaptations. Assuming a knowledge of thermodynamics, the early chapters cover refrigerants and refrigerating cycles, heat transfer, and fluid flow. After consideration of general systems and mechanical parts the refrigerating machines are discussed, including operation and testing. There are also chapters on air conditioning, cold storage, ice manufacture, and other applications.

RELATIVITY THEORY OF PROTONS AND ELECTRONS. By Sir A. S. Eddington. Macmillan Co., New York; University Press, Cambridge, England, 1936. Cloth, 7 × 11 in., 336 pp., tables, $5.50. A companion volume to his "Mathematical Theory of Relativity," the central problem being to ascertain the conditions which fix the amount of mass and electric charge carried by protons and electrons. The object has been to secure harmonization, not unification, of relativity and quantum theory, in order to combine the two conceptions in the solution of specific problems outside the range of either alone.

S.A.E. HANDBOOK, 1937 edition. Society of Automotive Engineers, New York. Cloth, 6 × 9 in., 774 pp., illus., diagrams, charts, tables, $5 to non-members ($2.50 to members). This annual handbook contains the specifications covering parts and fittings, materials, and small hardware in the automotive field, which have been set up by the S.A.E. It also covers standard tests, ratings, and codes. Section 8 is devoted to nomenclature and definitions. Information as to prices and method of securing the various standards is included.

SCIENCE MUSEUM, London. Handbook of the Collections Illustrating TIME MEASUREMENT. Part 2, Descriptive Catalogue, by F. A. B. Ward. His Majesty's Stationery Office, London, 1937. Paper, 6 × 10 in, 93 pp., illus., diagrams. (Obtainable from British Library of Information, 270 Madison Ave., New York, $0.65.) A descriptive catalog of the objects in the remarkable collection exhibited in the Time Measurement Section of the British Science Museum. The items are arranged chronologically within various groups, and are accompanied by illustrations in some cases.

STRENGTH OF MATERIALS. By A. P. Poorman. Third edition. McGraw-Hill Book Co., New York and London, 1937. Cloth, 6 × 9 in., 314 pp., diagrams, charts, tables, $3. This standard textbook covers the field of elementary strength of materials. It includes stresses and strains in general, riveted and welded joints, torsion of shafts, stresses and deflections of beams of various types, column formulas, and resilience. Illustrative problems and useful tables are given in order to show practical applications of the theories developed.

TECHNIQUE OF MARKETING RESEARCH. Prepared by the Committee on Marketing Research Technique of the American Marketing Society. McGraw-Hill Book Co., New York, 1937. Cloth, 6 × 9 in., 432 pp., illus., diagrams, charts, tables, $4. A comprehensive review of methods for investigating the problems that arise in connection with marketing policies, salability of products, markets, selling, etc. The purpose is to supply the needs of business men and students with a technique through which these problems can be approached scientifically.

TESTING OF INTERNAL COMBUSTION ENGINES. By S. J. Young and R. W. J. Pryer. D. Van Nostrand Co., New York, 1937. Cloth, 6 × 9 in., 200 pp., illus., diagrams, charts, tables, $3.25. A description of tests and testing methods, explaining just what is to be found out in each test, the equipment and setup requisite for the experiment, and the actual procedure and recording of results. Some of the headings covered are: Engine timing, brake horsepower tests, fuel consumption, indicator tests, and heat losses.

TOOL STEEL SIMPLIFIED. By F. R. Palmer. Carpenter Steel Co., Reading, Pa., 1937. Cloth, 6 × 9 in., 316 pp., illus., diagrams, charts, tables, $3.50. The purpose of this book is to place in the hands of toolmakers the type of knowledge possessed by the tool-steel expert. The four parts cover fundamentals, selection of right tool steel, properties, heat-treatment and testing, and "things worth knowing." The "matched set" method of selection is illustrated by the use of Carpenter Steel Company products and trade names.

VALUATION OF PROPERTY. Two volumes. By J. C. Bonbright. McGraw-Hill Book Co., New York and London, 1937. Cloth, 6 × 9 in., 1271 pp., $12. A presentation of the results of a research in legal and economic theories of property valuation. Vol. 1 covers concepts of value, methods of valuation, and valuation for specific legal purposes. Vol. 2 covers various specific cases of valuation under certain rules, tax restrictions, and other legal considerations. It also includes both a case index and a subject index.

THIS MONTH'S AUTHORS *and* PAPERS

ELECTRICITY plays an important part in three phases of transportation; trunk-line electrification, Diesel-electric trains and locomotives, and urban streetcar and rapid-transit systems. These applications are discussed at some length in the paper "Modern Electric Units in Transportation," and outstanding examples are cited. Advantages of the three units available for long-haul operation, steam locomotives, complete electrification, and Diesel-electric motive power, are presented together with their disadvantages, and the author, H. L. ANDREWS, points out that every problem must be studied separately because, in many cases, operating conditions may govern the final selection which involves the old problem of balancing increased fixed charges on additional capital involved against economies of operation. Data on the number of passengers that can be handled per hour by various transportation units and the comparative cost per route mile are included.

Mr. Andrews was graduated from the University of Missouri in 1910 with the degree of B.S. in electrical engineering and has been in the employ of the General Electric Company ever since. After two years in the testing department, he was transferred to the railway-motor department and, in 1916, to the railway-engineering department. From 1917 to 1925, Mr. Andrews was in charge of car equipment and was then appointed assistant engineer in administrative charge of the department. In 1929, he was promoted to engineer and assumed the responsibility for general commercial matters in the transportation field. Mr. Andrews was elected vice-president in charge of the activities connected with steam-railroad electrification in 1934, and, more recently, his duties were enlarged to include all transportation activities of the company.

WEAR ANALYZED QUALITATIVELY

Greater knowledge of the surface-fatigue characteristics of materials will prove valuable in studying the dynamics of many types of mechanism and measuring the actual intensity of the dynamic loads existing there, according to EARLE BUCKINGHAM, author of "Qualitative Analysis of Wear," which is the first in a series of progress reports dealing with recent work of the A.S.M.E. Special Research Committee on the Strength of Gear Teeth. Six types of gear-tooth wear are discussed briefly, and the report points out that the problem is complicated by the interaction of different materials upon each other and also stresses the importance and uses of endurance limits of materials.

The author is professor of mechanical engineering at the Massachusetts Institute of Technology. During the World War, he was chief gage inspector for the Canadian Car & Foundry Co., chief inspector on fuse subcontracts for the Eddystone Ammunitions Company, and assistant equipment engineer with the Winchester Repeating Arms Company. From 1919 to 1925, Mr. Buckingham was engineer with the Pratt & Whitney Co., and for the last 12 years has been a member of the faculty of Massachusetts Institute of Technology. He has been a member of the National Screw Thread Commission since 1920, and has been prominent in the work of several A.S.M.E. special research committees and sectional committees of the American Standards Association.. Mr. Buckingham has been a member of A.S.M.E. since 1913.

WEATHER FORECASTING

Weather prediction until recently could truthfully be termed a psuedo science since purely empirical or statistical considerations formed its basis; now an accuracy of over 90 per cent has been attained in the 24-to-36-hour forecasts, according to the paper "The Technique of Weather Forecasting," provided sufficient data are available.

Air-transport companies were the first users of detailed weather forecasts, which were so accurate that they are now being applied suc-

cessfully to other and widely diverse industries, such as production of motion-pictures, growing and marketing of citrus fruits, department-store advertising, and construction of dams and highways.

IRVING KRICK, the author, has been assistant professor of meteorology at the California Institute of Technology, Pasadena, Calif., since 1935. He was graduated from the University of California in 1928 and has been at the Institute since 1932 as a teaching fellow, an instructor, and in his present capacity. California Institute of Technology conferred the degree of M.S. in 1933 and followed this a year later with a Ph.D.

OIL INDUSTRY IN MICHIGAN

Petroleum production in Michigan is only 12 years old, but, since that time, the state has assumed a relatively important position in the industry and approximately 1500 bbl is now being taken out of the ground daily. While the gasoline refined from this crude has a low octane rating, which makes it an unsatisfactory fuel, the refiners have overcome this handicap by producing high-grade lubricating oils, naphthas, solvents, kerosene, and fuel oils. "The Oil Industry in Michigan," describes briefly the geological characteristics of the State and presents data on the various fields that have been producing for some time as well as the recently discovered ones. C. R. MILLER, the author, considers that Michigan's future as an oil-producing state is problematical but inclines toward the belief that new fields will be discovered from time to time and that these will keep the State on the map as an oil producer.

The author is a native of Wyandotte, Mich. He was graduated with an A.B. in 1911 from Albion College and taught science in the Wyandotte High School for the next three years. In January, 1915, he entered the employ of the White Star Refining Company, where his work was of a technical nature and included the development of the company's laboratory and its supervision for a number of years. In his present position of consulting engineer for the White Star-Ohio Division of the Socony-Vacuum Oil Company, Inc., Mr. Miller has general supervision over specifications for all products manufactured in the Detroit territory. This work has involved the investigation of various materials entering into the manufacture of finished products, with special reference to crude oil.

MECHANICAL ENGINEERS IN THE CHEMICAL INDUSTRY

All of us are curious about the other fellow's job. In the paper, entitled "Work of Mechanical Engineers in Chemical Plants," JAMES ELLIS has told how mechanical engineers may fit themselves into a type of industry, the so-called process industry, which is rapidly growing in importance. Some of these industries are large and some small, yet in all of them the problems that he outlines are found.

The author, who has been an A.S.M.E. member since 1921, is in excellent position to tell what is expected of a mechanical engineer in these industries inasmuch as he has been employed by one of them, the Tennessee Eastman Corporation, Kingsport, Tenn., for 12 years. Since 1932, he has been in charge of its engineering and service division, a large organization that is doing the type of engineering which he describes.

HOW TO EDUCATE AN ENGINEER

Most engineers will admit after reading what GEO. A. ORROK had to say on the "Aims and Objectives of an Engineering Education" at the recent meeting of the Society for the Promotion of Engineering Education that if they had been reared in his formula they would be able, as he is, to tackle any kind of an engineering job. Oddly enough the engineering phases of Mr. Orrok's education were self-acquired, as he himself points out, but they were based on a sound primary and secondary school training, a fruitful experience in chemistry at M.I.T., and a native intellectual curiosity that keeps him forever young. Schoolmasters of the better sort overcame the boyish instinct to resist education and left a lasting impression of the importance of good teachers. Arguing for perspective as against departmentalized specialization, Mr. Orrok would break down in so far as it is possible to do so the artificial walls within which much formalized education is isolated into compartments. Mr. Orrok tells just enough about some of his engineering experiences to show that it is useless to think of him solely as a designer of central power stations, for which his long association with the New York Edison Company and Thos. E. Murray has made him most familiarly known to engineers of this generation. At present a consulting engineer in New York, he was recently made an honorary member of The American Society of Mechanical Engineers.

ENGINEERS AND SECURITIES

Certain desirable effects on corporate finance have indirectly resulted from the passage of the Securities Act in 1933 and the Securities Exchange Act a year later, and a change in the approach to accounting problems and an improvement in the manner of presenting financial statements are already apparent. How these have been brought about and the possibilities of additional legislation to supplement the two Acts are discussed in "The Engineer and the Issue of Securities." After outlining the broad liability provisions of these acts regarding untrue statements or the omission of essential facts in a prospectus, A. I. HENDERSON comments on some of the problems involved in the preparation of a registration statement for a new issue of securities, cautions engineers on the need for exactness in the language used in preparing reports to supplement such a statement, points out the importance of uniformity in all sets of balance sheets and income statements, and stresses the point that some one officer of a corporation should be thoroughly familiar with both Acts and the rules and regulations of the Securities and Exchange Commission.

Mr. Henderson received an A.B. degree upon being graduated from Harvard in 1913, attended Cambridge University, England, for one year, and spent the next two years at the Harvard Law School from which he was graduated in 1916, cum laude. He was stationed on the Mexican border with the New York National Guard for some time prior to the World War and served with the artillery in France and with the Army of Occupation in Germany until early in 1919, when he was transferred to the finance section of the Paris Peace Conference and remained there for three months. In 1920, Mr. Henderson entered the law office of Cravath, Henderson & de Gersdorff, New York, N. Y., and became a member of the firm in 1923. He severed this connection in December, 1928, to accept a partnership in the investment brokerage house of J. & W. Seligman & Co. and remained there until June, 1932, when he resumed the practice of law as a member of the firm of Cravath, de Gersdorff, Swaine & Wood, which had succeeded Cravath, Henderson & de Gersdorff. Since 1933, Mr. Henderson has specialized in problems arising under the Securities Act and the Securities Exchange Act.

UNFIRED PRESSURE VESSELS

Designing an unfired pressure vessel that is subjected to external pressure is a rather complicated process because usually all the information that the designer has to start with are the length and diameter of the proposed vessel and the maximum external pressure to be applied. Numerous theoretical and empirical formulas are given in the A.S.M.E. Boiler Code, but their application involves considerable computation. To present the rules in the simplest possible form, the formulas involved are represented by curves, and they are presented and discussed in the article on theoretical and empirical equations represented in rules for construction of unfired pressure vessels subjected to external pressure, which has been prepared by D. F. WINDENBURG at the request of the A.S.M.E. Special Research Committee on Strength of Vessels under External Pressure.

The author was graduated from Cornell College, Mt. Vernon, Iowa, with an M.A. degree. He pursued graduate courses in mathematics and physics at the University of California for two years and then entered the teaching profession. Mr. Windenburg was head of the mathematics department at the Polytechnic College of Engineering, Oakland, Calif., for three years and held a similar position at the Long Beach Junior College, Long Beach, Calif., for two years. In January, 1929, he was appointed assistant physicist in the Bureau of Construction and Repair, Navy Department, and assigned to the Experimental Model Basin at the Washington Navy Yard, where he has remained ever since. Mr. Windenburg has written several papers relating to thin cylindrical shells under external pressure which have been published in MECHANICAL ENGINEERING and A.S.M.E. Transactions.

FACING THE TAX PROBLEM

This month's review of economic literature from the Economic Department of the Massachusetts Institute of Technology entitled "Facing the Tax Problem" is by DONALD S. TUCKER, professor of economics in that department, who has contributed previously to this series.

A.S.M.E. NEWS

And Notes on Other Engineering Activities

Oil and Gas Power Division to Be Guest of Penn State for Its Meeting, August 18–21

Final Program of Technical Papers and Sessions

ONCE again the Oil and Gas Power Division of the A.S.M.E. will be the guest of the Pennsylvania State College for its annual national meeting to be held under the joint auspices of the Division and the Central Pennsylvania Section. Those who have attended previous meetings in this delightful college environment in the midst of the beautiful forest-clad mountains of central Pennsylvania know that a cordial welcome awaits them and that the meeting provides the opportunity of combining a restful outing with a splendid technical program. Those who have not attended before are urged to do so and to see for themselves why Penn State is so popular with the members of the Oil and Gas Power Division.

The official program for the meeting follows:

WEDNESDAY, AUGUST 18

9:30 a.m.

Registration opens at the Nittany Lion Inn. A registration fee of $1 covers a complete file of preprints of all papers to be presented.

2:00 p.m. General

Chairman: Ernest Nibbs, Electric Boat Company and chairman A.S.M.E. Oil and Gas Power Division

Welcome by the Dean of Engineering

Progress Reports, by American Locomotive Company, Atlas-Imperial Diesel Engine Company, Caterpillar Tractor Company, Davenport-Besler Corporation, De La Vergne Engine Company, General Motors Corporation, Hercules Motors Corporation, Ingersoll-Rand Company, Nordberg Manufacturing Company and others

U. S. Navy Contributions to Diesel Engine Development, by E. C. Magdeburger, Bureau of Engineering, U. S. Navy Department

THURSDAY, AUGUST 19

9:30 a.m. Fuels–Lubrication

Chairman: Carl Behn, National Supply Company of Delaware, Otto Engine Division

Lubrication Problems in Connection With High-Speed Diesel Engines, by C. G. A. Rosen, Caterpillar Tractor Company

Correlation of Laboratory Tests on Fuel Oils With Field Operation, by W. F. Joachim, U. S. Naval Experiment Station

2:00 p.m. Transportation

Chairman: Harte Cooke, American Locomotive Company

Recent Developments in Automotive-Type Diesel Engines, by O. D. Treiber, Hercules Motors Corporation

Diesel-Electric Bus Operation, by Martin Schreiber, Public Service Coordinated Transport Company

FRIDAY, AUGUST 20

9:30 a.m. Operating

Chairman: L. M. Goldsmith, Atlantic Refining Company

Oil Engine Power Cost Report, by H. C. Major, chairman, Oil Engine Power Cost Subcommittee

Sewerage Gas Engines, by W. B. Walraven, Springfield (Ill.) Sanitary District

Waste Heat Recovery From Diesel Engines, by Glenn C. Boyer, Burns & McDonnell Engineering Company

The Penn State Method of Testing Diesel Fuels, by J. S. Chandler, The Pennsylvania State College

2:00 p.m.

Committee Meetings and golf tournament

7:00 p.m.

Banquet, Informal, Nittany Lion Inn

SATURDAY, AUGUST 21

9:30 a.m. Research

Chairman: P. H. Schweitzer, Penn State College

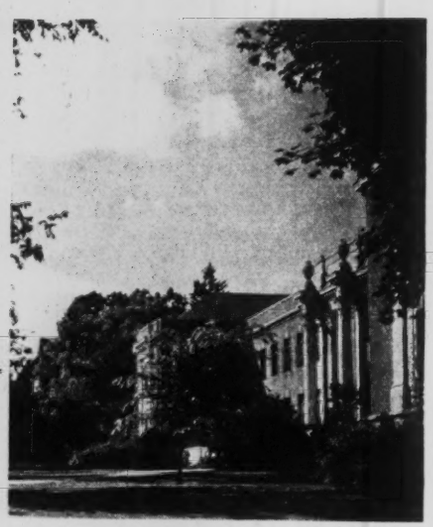
Oil Flow Through Fuel Nozzles, by K. J. De Juhasz, Penn State College

Polymerization of Fuel Oils, by Gustav Egloff, Universal Oil Products Company

The Nittany Lion Inn, Headquarters

The Nittany Lion, an early colonial inn, headquarters for the meeting, is charmingly located on the College Campus adjacent to the College's 18-hole golf course which is available to guests at the meeting. The Inn has unusually spacious lounges and parlors and provides an ideal opportunity to make

SUMMER AT PENN STATE



ON THE CAMPUS AT PENN STATE

new friendships and to renew old ones which is one of the most cherished features of these meetings. The women will find these rooms particularly delightful for a quiet game of bridge while the men are busy with the technical sessions.

Both the time and the place make this an ideal occasion for them to accompany their husbands for a delightful vacation that is distinctly different. A special Committee is making plans for their enjoyment.

On Wednesday evening an informal get-together and dance will be held at the Nittany Lion Inn. A bridge tea is planned for the women on Wednesday afternoon and on Friday evening there will be a banquet at the Inn. Other delightful entertainment will be planned including a tour of the College campus, excursions, and golf, tennis, swimming, and horseback riding.

Reservations for accommodations should be made in advance with Prof. F. G. Hechler, chairman of the Committee on Arrangements, Pennsylvania State College, State College, Pa.

Exhibit

The exhibit of Diesel-engine parts and accessories will be held in the Inn. Short talks by the exhibitors will again be a feature of the meeting. Exhibitors include the Aluminum Company of America, American Air Filter Company, De Laval Separator Company, Diesel Equipment Corporation, *Diesel Power*, Ex-Cell-O Corporation, Goulds Pumps, Inc., Hercules Motors Corporation, Illinois Testing Laboratories, Koppers Company, American Hammered Piston Ring Division, Timken Roller Bearing Company, United American Bosch Corporation, and J. H. H. Voss, Incorporated.

Committees

Handling the arrangements for the meeting are the following: F. G. Hechler, chairman, E. R. Queer, P. H. Schweitzer, Oliver F. Allen, L. T. Brown, J. S. Chandler, J. S. Doolittle, C. W. Good, Raymond Haskell, L. H. Morrison, Paul Newman, P. J. Reber, and F. M. Torrance.

The Technical Program Committee consists of L. H. Morrison, chairman, Harte Cooke, and Lee Schneitter. The Exhibits Committee has K. J. DeJuhasz as chairman, and Carl Behn, Ralph Miller, R. Y. Sigworth, and F. C. Stewart. The Committee on Entertainment and Sports with E. L. Keller, chairman, has as members H. A. Everett, W. K. Gregory, N. R Sparks, and R. W. Wadman. There is a Daily Bulletin Committee, with C. L. Allen, chairman, and Ernest Hartford, A. H. Zerban, and W. G. C. Thompson.

Papers for A.S.M.E.-A.I.M.E. Joint Fuels Meeting in Pittsburgh, Oct. 27–29

AT THE MEETING which the Fuels Division of the A.S.M.E. is to hold jointly with the Coal Division of the A.I.M.E. in Pittsburgh, Pa., October 27–29, the following papers are now being scheduled for presentation:

By the Fuels Division, A.S.M.E.

Selection of Coal for Pulverizers, by B. E. Tate, chief engineer, power plant, National Cash Register Company, Dayton, Ohio

Underfeed Stokers From Standpoint of Coal Selection, by J. E. Tobey, manager, fuel-engineering department, Appalachian Coals, Inc., Cincinnati, Ohio

Chain- or Traveling-Grate Stokers—Bituminous and Anthracite, by G. A. Anbro, power engineer, Colgate-Palmolive-Peet Co., Jersey City, N. J.

Small Underfeed Stokers—Less Than 150 Hp, Bituminous and Anthracite, by the Engineering Committee of the Stoker Manufacturers' Association, B. M. Guthrie, chairman, and Frank Hoke, R. E. Young, Chester Kay, T. A. Marsh, E. C. Webb, and A. O. Dady

Summary of Papers on Coal Utilization and Relation to Coal Research, Particularly in Fundamental Aspects, by Ralph A. Sherman, fuel engineer, Battelle Memorial Institute, Columbus, Ohio

By the Coal Division, A.I.M.E.

Effect of Coal Preparation and Value to the Consumer, by H. F. Hebley, Commericial Testing and Engineering Company, Chicago, Ill.

Present Available Methods of Burning No. 4 Buckwheat Coal, by Allan J. Johnson and E. I. Buller, Anthracite Institute Laboratory, Primos, Pa.

Use of Catalysis in Combustion of Coal, by P. Nicholls, Fuels Section, U. S. Bureau of Mines, Pittsburgh, Pa.

Interpretation of Laboratory Coal Tests, by G. B. Gould, president, Fuel Engineering Company, New York, N. Y.

Theoretical and Practical Aspects of Segregation in the Handling of Coal, by D. R. Mitchell, Urbana, Ill.

Fundamental Factors Involved in the Dust-proofing of Coal, by M. E. Fife, Mellon Institute, Pittsburgh, Pa.

Arrangements are now being made by the local committee in Pittsburgh for visits to plants where apparatus may be seen illustrative of that referred to in the papers but final details are not ready.

It is hoped that more detailed information may be given in the next issue of MECHANICAL ENGINEERING.

Machine Shop Practice Division to Meet with the A.W.S.

AT THE annual meeting and welding exposition of the American Welding Society to be held from October 18 to 22 at Atlantic City, N. J., the Machine Shop Practice Division of the A.S.M.E. will sponsor one technical session. This session is scheduled for Tuesday afternoon, October 19. Two papers will be presented, one on "Resistance-Welding Fabrication" by J. M. Cooper of the General Electric Company, and the other on "Fusion-Welded Fabrication" by H. N. Blackmon of the Westinghouse Electric & Manufacturing Co.

Sessions will cover the subjects of industrial research, fundamental research in welding, fabrication, alloy steels, shipbuilding, and railroads.

Headquarters for the meeting will be at the Traymore Hotel where all technical sessions will be held. The welding exposition will be in Convention Hall.

R. L. Sackett Honored

R. L. SACKETT

CONCLUDING 22 years of service to engineering education at the Pennsylvania State College, R. L. Sackett, vice-president, The American Society of Mechanical Engineers, retired as dean of engineering at that institution on July 1, 1937.

At the seventeenth annual Industrial Training Conference, held at State College in May, Dean Sackett was presented with an illuminated scroll in honor of his leadership in engineering fields, and for his contribution to the college the Class of 1937 dedicated its class book to him, the formal dedication taking place at a dinner given for him.

Strong and vigorous and in splendid health, Dean Sackett plans to spend much of his time in the coming months in New York, actively directing the important work of the Committee on Selection and Guidance of Engineering Students, of which he is chairman, of the Engineers Council for Professional Development.

The Members' Page

A Forum for Frank Discussion by A.S.M.E. Members

The A.S.M.E. and the N.S.P.E.

THE MEMBERS' PAGE:

The rapidly growing National Society of Professional Engineers has a valid claim upon many members of the founder societies for support, and in times of stress might even claim their membership to the exclusion of membership in the older societies. It is my belief that the time is ripe for The American Society of Mechanical Engineers to adopt a definite policy for the guidance of its future relationship with the N.S.P.E. Should the N.S.P.E. be ignored, should a program toward ultimate unification be pursued, or should a policy of close cooperation in matters of common interest be adopted? The initial step in the consideration of this problem is a clear understanding of the aims of the A.S.M.E. and those of the N.S.P.E.

The A.S.M.E. is an organization, almost sixty years old, devoted to the promotion of the art and science of mechanical engineering. It is composed largely of men active in the practice of some form of mechanical engineering who are willing to further the aims of the Society at some personal sacrifice if necessary. These aims may be classified briefly as encouragement of original technical research, promotion of standardization committees that trade practices may be made uniform, and the summation of individual experiences so that all may benefit. The results of these activities are published in the Transactions and in MECHANICAL ENGINEERING.

The N.S.P.E., a young but vigorous association of engineers, is composed of men holding state professional-engineers' licenses. The society's objective is to advance the professional and economic interests of the engineer through legislation. It proposes to accomplish this end through perfection and enforcement of the present licensing laws. It also proposes to protect the status of professional engineers by active opposition to legislation tending to restrict their rights of practice, and by correction of local laws and ordinances which conflict with licensing laws. The members are kept informed of these activities through monthly county meetings and a nontechnical magazine.

The founder societies and the N.S.P.E. are organized along lines best suited to carry out their respective programs. The qualifications necessary for membership in a founder society so restrict its members that it is ill-fitted to carry out a program such as that sponsored by the N.S.P.E. On the other hand, the N.S.P.E., drawing members as it does from all the founder societies, is ill-fitted to attempt any program other than a general one which will have the support of all its members. In other words, each society, organized as it is, is best suited for the promotion of its specialized program, and unification of all societies would contribute little if anything to the efficiency with which these programs are executed.

These programs involve a certain amount of expense for administration, housing, and publication. Roughly speaking the cost per member of the A.S.M.E. program is $20 per year. On the same basis, the N.S.P.E. program costs $10 per year per member, the member's annual dues. These costs must be viewed as inherent in the performance of certain functions, and are unavoidable as long as those functions are performed. At present there is little if any duplication of the founder societies' programs by the N.S.P.E. Therefore, were unification of the founder societies with the N.S.P.E. to be effected, the combined programs would cost each member about $30 per year. The cost of the programs cannot be side-stepped merely by shifting the burden of administration. In fact, dues less than $30 might well be looked upon with suspicion, as indicative that either the technical or the legislative programs were being curtailed. It is therefore doubtful whether unification would mean an annual saving in dues for the individual members.

The N.S.P.E. can hardly be ignored. It is a large and growing organization of national scope, which draws a large share of its members directly from the founder societies. Its program concerns the economic welfare of the accredited professional engineer and is based upon the strengthening of laws already in force. To ignore this new society would be to presuppose a short-lived existence. Yet its activities and membership are such that a long and useful life is most probable.

Although unification of all engineering societies seems remote, the N.S.P.E. cannot be ignored as a distinct factor affecting the well-being of members of all founder societies. The pursuit of their respective programs by these latter societies, each independent of the other, does not preclude the closest cooperation between them and the N.S.P.E. on matters affecting the economic welfare of their members. It is therefore my belief that the New York Engineering Council proposed by the Metropolitan Section of the A.S.M.E. should include as one of its duties cooperation with the N.S.P.E. on matters of mutual interest.

WM. H. LARKIN, 3D.[1]

Mechanical-Engineering Education

THE MEMBERS' PAGE:

I have read with considerable interest Professor Eidmann's letter on "Mechanical-Engineering Education" in the June, 1937, issue of MECHANICAL ENGINEERING. I heartily indorse his proposal and believe the successful operation of the plan would be of great benefit to engineers and to the Society.

As an educator, I have continually impressed on graduating classes the need of a continuation of their studies after graduation. The question always comes up as to how and where. Many engineers, because of their location and time schedules, cannot attend established graduate schools. Moreover, many graduate schools place their entrance requirements so high, due to their restricted capacities, that a large percentage of our engineers find it impossible to gain admission.

I believe that the A.S.M.E. would be doing a great service in sponsoring centers of advanced and specialized instruction. Almost every city has an A.S.M.E. Local Section that might well become the center of such instruction. I urge the Council to consider carefully Professor Eidmann's plan.

FRANK D. CARVIN.[2]

[1] Tompkinsville, Staten Island, N. Y. Jun. A.S.M.E.

[2] Professor of Mechanical Engineering, Newark College of Engineering, Newark, N. J. Mem. A.S.M.E.

Applied Mechanics and Hydraulic Divisions Vote Ithaca Meeting Highly Successful

ONE OF the most interesting meetings ever held by either was that at which the Applied Mechanics and Hydraulic Divisions of the A.S.M.E. joined forces in Ithaca, June 25 and 26. Technically and socially it was voted highly successful and members of the Divisions are indebted both to Cornell University and to Prof. F. G. Switzer and his local committee for two unusually profitable days.

At the first session Friday morning, on vibration, four papers were presented. Two dealt with the use of rubber as a means of isolating vibration, one considered features of the vibration of a nine-cylinder engine, and one discussed the interesting work being done at Stanford University on the influence of earthquakes on buildings.

In the afternoon at a joint session of both Divisions a lively discussion followed the presentation of three papers dealing with cavitation, turbulence, and flow problems.

Simultaneous Sessions on Cavitation and Elasticity

On Saturday morning sessions were held simultaneously on cavitation and on elasticity. At the former were discussed the pitting resistance of metals under cavitation conditions and the relative resistance to cavitation erosion by the vibratory method. At the session on elasticity four papers were read dealing with curved flexural springs, stresses in three-dimensional pipe lines, working stresses for fluctuating loads, and torsion of rectangular tubes. Six papers were presented by title.

Saturday afternoon was devoted to a round-table conference by the Hydraulic Division on the present status of cavitation research in the United States and Canada. It was an unusual privilege to have representatives from all of the groups now engaged in cavitation research present to discuss this problem and to report upon their work and the programs contemplated for the future. The following research investigations were reported upon: Pennsylvania Water & Power Corporation, Massachusetts Institute of Technology, Princeton University, University of Toronto, Shawinigan Water & Power Company, Canada, and U. S. Naval Propeller Testing Laboratory.

Following the discussion of the research program, the meeting was thrown open to discussion on the definition of cavitation action, and it was generally agreed that a sharp distinction should be drawn between cavitation itself and the pitting or erosive action resulting from cavitation. A subcommittee of the main Cavitation Committee is to be appointed to prepare a definition which would be recommended for general use. Subcommittees are also being organized to prepare recommended methods for determining the relative resistance of materials to pitting under cavitation conditions and also for the recommended methods by which the characteristics of turbines, pumps, and propellers can be established under cavitation conditions.

The meeting passed a resolution proposed by Prof. Lewis F. Moody, seconded by Carroll F. Merriam, that letters be sent to Dr. Spannhake and Dr. Thoma in Germany in recognition of their contributions to the study of cavitation.

Simultaneously a session was held on plasticity by the Applied Mechanics Division at which papers considering plastic torsion and creep of metals were presented.

Particularly noticeable at all of the technical sessions was the interesting and lively discussion

Following the technical sessions on Saturday the executive committee of the Applied Mechanics Division held a meeting at which the program for the Annual Meeting was discussed and regular Division activities talked over.

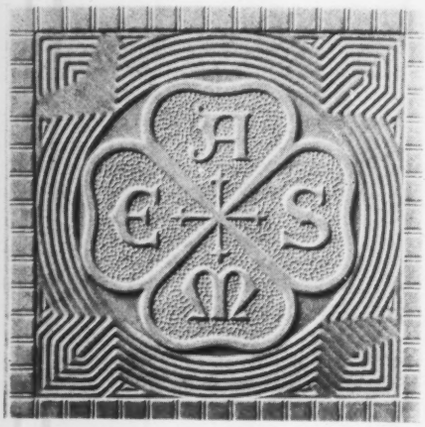
The meeting, however, had its lighter side when elasticity, vibration, cavitation—even plasticity—were forgotten or outranked by a picnic supper at Taughannock Falls. Previously on Friday special trips and a tea had been arranged for the women in attendance at the meeting.

Dr. H. J. Gough Speaker at Dinner

The dinner on Saturday evening was well attended. C. R. Soderberg was an able toastmaster. The principal speaker was Dr. H. J. Gough of the National Physical Laboratory in England who told of the different types of research work conducted there. Provost A. R. Mann of Cornell University brought greetings and a welcome to the meeting. Short talks were given by S. Logan Kerr of the Hydraulic Division and C. E. Davies, secretary of the A.S.M.E.

A.S.M.E. Emblem in Lobby of New Mellon Institute Building

SEVERAL parts of the new home of Mellon Institute at Pittsburgh have been invested with symbolic meaning to render the art therein emblematic of the purpose of the institution, the beneficence of science, the qualities of scientific research, the origin and advancement of chemistry, and the value of industrial research.



Medallions bearing the emblems of American scientific and professional societies, representative of the principal fields of science and technology constitute an important part of this symbolism.

These medallions signify the general character and breadth of the Institute's recognition of, indebtedness to, and collaboration with these organizations and their realms and also the scope of scientific research, both pure and industrial, particularly as conducted at the Institute.

The accompanying illustration shows the A.S.M.E. emblem as it appears in the lobby of the building.

J. M. Mousson Receives First James H. McGraw Prize

ON JUNE 4, during the annual convention of the Edison Electric Institute, J. M. Mousson, member of the A.S.M.E. and hydraulic engineer of the Safe Harbor Water Power Corporation, Baltimore, Md., received the first James H. McGraw Prize for 1937. This award, which is one of three made annually by the Institute, was in recognition of his paper, "Practical Aspects of Cavitation and Pitting," as the most meritorious paper pertaining to any engineering or technical subject relating to the electric light and power industry.

Members of A.S.M.E. in Commencement News

SEVERAL MEMBERS of the A.S.M.E. were the recipients of degrees conferred at recent commencement exercises, and others delivered commencement addresses. Among these were the following:

R. L. SACKETT, vice-president of the A.S.M.E., dean emeritus of engineering, Pennsylvania State College, Doctor of Engineering, University of Michigan.

C. F. SCOTT, professor-emeritus of electrical engineering at Yale University, and chairman, Engineers' Council for Professional Development, Doctor of Science, The Ohio State University. Dr. Scott was elected president of the Alumni Association at its recent meeting.

RALPH E. FLANDERS, past-president of the A.S.M.E., and president of the Jones & Lamson Machine Co., Springfield, Vt., delivered the commencement address at the Polytechnic Institute of Brooklyn on June 16. His subject was "The Engineer and His World."

S. F. VOORHEES, senior partner of Voorhees, Gmelin & Walker, New York, N. Y., and past-president of the American Institute of Architects, Doctor of Engineering, Princeton University.

GANO DUNN, president of the J. G. White Engineering Corporation, New York, N. Y., and president of the National Research Coun-

cil, delivered the address to the graduating class of the Massachusetts Institute of Technology, Cambridge, Mass.

C. F. KETTERING, president and general manager of the General Motors Research Corporation, Detroit, Mich., and past-president of the Society of Automotive Engineers, Inc., Doctor of Science, New York University. He was cited as "a leader in a field of activity which has only been in being for a generation, namely, the organized and sympathetic attempt to find, through research, new applications of the principles of science to large-scale industry."

WALTER J. WOHLENBERG, Sterling professor of mechanical engineering at Yale University, Doctor of Engineering, University of Nebraska.

FREDERICK KEY, vice-president and engineer in charge of design for the Key Company, East St. Louis, Ill., Doctor of Mechanical Engineering, of University of Tulsa. He was cited as a "distinguished engineer and inventor, leader in industrial progress, whose vision of man's needs, consecration to the task of fulfilling them, and eternally youthful spirit have made his long and active life of great value in his chosen field."

MALCOLM F. MCCONNELL, general superintendent of the Homestead Works of the Carnegie-Illinois Steel Corporation, Munhall, Pa., Doctor of Science, University of Pittsburgh, for "citizenship and achievements in industry."

A.S.M.E. Calendar

of Coming Meetings

August 18–21, 1937
Oil and Gas Power Meeting
Pennsylvania State College
State College, Pa.

October 4–6, 1937
Fall Meeting
Erie, Pa.

October, 1937
Wood Industries Meeting
Grand Rapids, Mich.

October 15, 1937
Textile Meeting
Boston, Mass.

October 27–28, 1937
Joint Meeting of A.S.M.E. Fuels and A.I.M.E. Coal Divisions
Pittsburgh, Pa.

December 6–10, 1937
Annual Meeting
New York, N. Y.

March, 1938
Spring Meeting
Los Angeles, Calif.

June 20–24, 1938
Semi-Annual Meeting
St. Louis, Mo.

Other Engineering Activities

Pump-Testing Laboratory at University of California

THE department of mechanical engineering at the University of California has established a laboratory for the study of vertical-shaft pumps. The program of research has been worked out in cooperation with the Division of Agricultural Engineering and the Division of Irrigation Investigations and Practice of the College of Agriculture and with the pump manufacturers. The work of this laboratory will include: Research in the field of deep-well and propeller pumps; analysis of laboratory and field methods of testing, development of testing standards and calibration of testing instruments; tests of motors, bearings and auxiliary equipment; tests of manufacturers' types; and acceptance tests of specific pumps.

Installation of the testing equipment is about completed and work will be started immediately. Initial projects are: Accuracy of methods of measuring water; normal characteristics of new deep-well pumps; friction losses in riser column; friction in bearings; effect of wear on pump characteristics; pump thrust loads; development of Pump Testing Code.

Arrangements have been made to borrow pumps and accessories for carrying out this program. Manufacturers interested in participating in this work should write to Prof. M. P. O'Brien, at the University of California.

A.I.E.E. Officers Elected for 1937–1938

W. H. HARRISON, assistant vice-president, department of engineering and operation, American Telephone and Telegraph Company, New York, N. Y., was elected President of the American Institute of Electrical Engineers for the year beginning August 1, 1937, as announced at the annual meeting of the Institute held in Milwaukee, Wis., during the annual summer convention of the Institute. The other officers elected were: Vice-presidents, I. Melville Stein, Philadelphia, Pa.; Edwin D. Wood, Louisville, Ky.; L. N. McClellan, Denver, Colo.; J. P. Jollyman, San Francisco, Calif.; M. J. McHenry, Toronto, Canada. Directors, C. R. Beardsley, Brooklyn, N. Y.; V. Bush (Mem. A.S.M.E.), Cambridge, Mass.; F. H. Lane (Mem. A.S.M.E.), Chicago, Ill. National treasurer, W. I. Slichter (Mem. A.S.M.E.), New York, N. Y. (reelected).

A.S.T.M. Officers for 1937–1938

THE American Society for Testing Materials has announced the election of its officers for 1937–1938 as follows: President, Prof. A. E. White (Mem. A.S.M.E.), University of Michigan, Ann Arbor, Mich.; vice-president, H. H. Morgan (Mem. A.S.M.E.), Chicago, Ill.; members of the executive committee, P. H. Bates, H. F. Clemmer, and G. E. F. Lundell, all of Washington, D. C., H. C. Mougey, Detroit, Mich., and R. L. Templin, New Kensington, Pa.

Officers of National District Heating Association Elected

AT THE twenty-eighth annual convention of the National District Heating Association held in Detroit, Mich., in May of this year, officers were elected as follows: President, T. E. Purcell (Mem. A.S.M.E.), Pittsburgh, Pa.; first vice-president, J. R. McCausland (Mem. A.S.M.E.), Philadelphia, Pa.; second vice-president, G. D. Winans, Detroit, Mich.; third vice-president, Edward Lenz (Mem. A.S.M.E.), New York, N. Y. Members of the executive committee: M. D. Engle (Mem. A.S.M.E.), Boston, Mass.; F. L. Witsell, Toledo, Ohio; J. M. Arthur, Kansas City, Mo.

H. W. Craver Heads Librarians

H. W. CRAVER

AT A meeting of the American Library Association held in New York, N. Y., during the week of June 19, 1937, Harrison W. Craver, director of the Engineering Societies Library, was elected president of the association.

Director Craver is a native of Illinois and a graduate of Rose Polytechnic Institute where he studied chemistry and from which he received the honorary degree of Doctor of Science in 1933. His technical and engineering work was carried on in various steel mills which he served as chemist, metallurgist, and superintendent of open-hearth work.

In 1900 Dr. Craver was invited to organize a technology department for the Carnegie Library of Pittsburgh, the first public library to attempt special services to engineers and manufacturers of the community. After two years spent at this task, he returned to the steel business as assistant superintendent of the newly organized Allegheny Iron and Steel Company, now the Allegheny Steel Company, in charge of the rolling mills.

The attractions of library work proving too strong to be resisted, Dr. Craver, returned to

the Carnegie Library of Pittsburgh as technology librarian and was later appointed librarian. In 1917 he came to the Engineering Societies Library as its librarian, where his knowledge of this profession and of the literature of technology have been fruitful in the direction of the largest engineering library in this country. Under his administration the library's extensive collection of books and pamphlets was satisfactorily catalogued.

Dr. Craver is a member of numerous scientific, historical, and library societies and clubs. His wide knowledge of scientific, engineering, and general literature and his facility in foreign languages, coupled with a librarian's sixth sense in ferreting out references on an infinite variety of subjects, have been important factors in his successful administration of the library.

American Chemical Society to Meet in Rochester

THE ninety-fourth meeting of the American Chemical Society will be held in Rochester, N. Y., September 6 to 10.

Seventeen professional divisions of the society and the microchemical section have scheduled sessions.

Dr. E. R. Weidlein, director of the Mellon Institute of Industrial Research, Pittsburgh, will deliver the annual presidential address of the Society on Tuesday evening.

At twenty-three symposia, special reports of developments affecting industry, nutrition, public health, pure science, and education will be presented.

A wide variety of papers will be heard at other divisional sessions.

Engineering Institute of Canada Celebrates Its Semicentennial

A Brief Résumé of an Impressive Program and Some of the Addresses

MEMBERS of The American Society of Mechanical Engineers who witnessed and took part in the brilliant events of the celebration of the Fiftieth Anniversary of the founding of the Society will have a keen appreciation of the significance to the engineers of the Dominion of Canada of the Semicentennial of The Engineering Institute of Canada, held at Montreal, June 15 to 18, 1937.

In the June, 1937, issue of the Institute's *Engineering Journal* is briefly recounted "The Story of the Engineering Institute of Canada," founded in 1887 as the Canadian Society of Civil Engineers. In this account are traced the history of engineering in the Dominion prior to the formation of the Institute, and sketches of famous Canadian engineers, with brief mention of some of the high points of the Institute's developments and its achievements.

The Semicentennial program covered four days at Montreal, with the Windsor Hotel as headquarters, and two spent in the environs of Ottawa, centered around the Chateau Laurier. Representing The American Society of Mechanical Engineers was a distinguished list of citizens of the Dominion and the United States, as follows:

W. S. Atwood, vice-president, Canadian Car and Foundry Co. Ltd., Montreal, Que., Canada.

C. E. Davies, secretary, The American Society of Mechanical Engineers, New York, N. Y.

N. R. Gibson, vice-president, Buffalo, Niagara and Eastern Power Corp., Buffalo, N. Y.

F. D. Herbert, president, Kearfott Engineering Co. Inc., New York, N. Y.

James H Herron, president, The American Society of Mechanical Engineers.

Albert Laurie, owner, Laurie & Lamb, Montreal, Que., Canada.

R. E. McAfee, manager, Eastern Branch, Babcock-Wilcox & McCulloch, Ltd., Montreal, Que., Canada.

Charles Penrose, vice-president, Day & Zimmermann, Inc., Philadelphia, Pa.

H. L. Seward, professor of mechanical engineering, Yale University, New Haven, Conn.

T. Kennard Thomson, consulting engineer, New York, N. Y.

W. E. White, development engineer, Northern Electric Co. Ltd., Montreal, Que., Canada.

H. H. Vaughan, president, Canadian Foreign Investment Corp., Montreal, Que., Canada.

Two events of more than passing human interest concerning the American Society of

AT THE SEMICENTENNIAL BANQUET OF THE ENGINEERING INSTITUTE OF CANADA

Civil Engineers, one sad and the other felicitous, are worthy of mention. The first was the sudden death, in Montreal, on the day preceding that on which he was to have addressed the Institute, of Harrison P. Eddy, past-president, the American Society of Civil Engineers, an event which shocked all engineers. The other was a cablegram of greeting from Palestine sent by George T. Seabury, secretary, A.S.C.E., who was on a Mediterranean holiday.

Tuesday was given over to the official opening of the Semicentennial, with President G. J. Desbarats, of the Institute, presiding, at which official representatives and greetings were received from engineering and learned societies the world over. Honorary memberships in the Institute were conferred on engineers of the Dominion, the United States, England, and France, and prizes were awarded. The afternoon sessions and those held on Wednesday were devoted to the reading of technical papers. Luncheons on Tuesday and Wednesday were occasions for addresses, two of which are abstracted in this account, and a banquet was held on Wednesday night, more of which is noted later. Thursday was given over to inspection tours, to a garden party and tea in the afternoon at McGill University, and a "smoking concert" in the evening. Friday and Saturday were spent at Ottawa, with a luncheon at noon followed by tours in the afternoon and a dinner and dance in the evening. Saturday provided opportunity for further visits.

For the manuscripts from which the few addresses were abstracted in what follows we are indebted to Capt. R. J. Durley, secretary, The Engineering Institute of Canada.

Lord Tweedsmuir Speaks at Banquet

THE banquet on Friday evening, held in the Rose Room of the Windsor Hotel, was a brilliant occasion. As the accompanying illustration imperfectly shows, the speakers' table was arranged in the form of a shield, the device of the Institute, filled in with flowers, on which the Institute's emblem, the beaver, was silhouetted against a white background. The guest of honor and principal speaker was His Excellency the Governor General of Canada, Lord Tweedsmuir, better known to some for his writings under the name of John Buchan. G. J. Desbarats, president of The Engineering Institute of Canada, presided, and Brig. Gen. C. H. Mitchell, who will be remembered by those who attended the Fiftieth Anniversary of The American Society of Mechanical Engineers, acted as toastmaster.

Lord Tweedsmuir congratulated the Institute on fifty years of vigorous and fruitful life and recalled the fact that he had been made an honorary member of it, although, he said, he had no knowledge of engineering to justify it.

Most professions, he continued, seemed to him to be empirical and to deal largely in speculations and generalities. But the engineer did not; he had to deal with hard facts. He knew that if he were not exactly right in his calculations he would be wholly wrong. That gave his mind a clearness and precision not common in other walks of life.

Engineering Profession Foundation of Civilized Society

The engineering profession, he said, had always been the foundation of any civilized society. In Canada engineers had to conquer space, and to adapt landscape to human needs. Great achievements already stood to the credit of Canadian engineers, but the conquest of wild nature had only begun. He had never tired of declaring that the future of the British Commonwealth depended largely on applied science, and that the engineer was the principal Empire builder.

He reminded his listeners, that the beauty and dignity of its landscape were among the chief assets of any nation and that it was most necessary to keep the balance between the aesthetic and utilitarian interest. In England, the countryside had absorbed the railways, as, in his opinion, no doubt it would the motor roads. It was necessary in such matters to get rid of narrow aesthetic fads and take a robust view of what constituted the picturesque.

However, the constructive powers of man must keep in some harmony with nature, and in a country like Canada, where nature in its wildest form was dealt with, the engineer should be something of an artist. To him the introduction of human interest did not spoil, but rather dignified, any landscape. In bridges, he said, there should be conscious artistic purpose, for the bridge was one of the most beautiful of human creations.

In conclusion he said that engineering had a great mission. Engineers had in their hands the making of the material background of a great nation. They were the pathfinders, the road makers, the cyclopean architects of a land whose horizons were not limited and whose dimensions no man could sense. He congratulated the Institute on its half-century of brilliant achievement and said that when it came to celebrate its centenary it would look back on its jubilee year as no more than a day of small things.

A. Surveyer proposed the toast "Our Guests," to which Sir Alexander Gibb, honorary member of the Institute, replied.

Toast—"The Institute"

In proposing the toast "The Institute," Edward P. Lupfer, member of the American Society of Civil Engineers, conveyed the greetings and felicitations of that society to its Canadian sister society and spoke of the long, peaceful, and friendly relations that had existed between the United States and Canada. "We admire and applaud," he said, "your faith in yourselves, your dignity, your farsightedness; we admire your unafraidness, your independence, your formal simplicity, your solidarity. Feeling as we do about you, a feeling engendered and tested over many decades of neighborliness, we look with confidence to walking beside you down the coming years, refreshed and strengthened and encouraged by your presence." E. A. Cleveland of the Institute replied to the toast.

President Herron's Address on Social Progress

AT the luncheon held in Windsor Hall on Tuesday, J. M. R. Fairbairn of the Institute presiding, the guests were welcomed by His Worship the Mayor of Montreal, and addresses were delivered by H. V. Potter, of London, England, representing the Society of Chemical Industry, and James H. Herron, president, The American Society of Mechanical Engineers, whose subject was "Contributions to Social Progress." Mr. Herron said in part:

Engineering developments have set up a new economic structure; and the greatest concern of the present day is that of harmonizing and balancing the forces arising from the changed situation so that employment, production, and consumption may keep pace with each other. Community customs have ceased to be sharply differentiated, rural life has been given the advantages of urban culture, and it is now possible for country and city to meet on a fairly equalized plane of social interest and behavior.

Civic organization has been compelled to adjust its operations to fit the onward press of mechanical advancement. New laws must be enacted and old laws revamped to fit the present needs. Greater responsibilities are imposed upon the government, while new means and sources of taxation must be sought to meet the added burden of expense.

Ethical and religious customs are affected slightly perhaps but certainly by the forward sweep of the material forces. Creeds are breaking down their walls of intolerance, and it is apparent that dispersion of education and culture through the facilities offered by design and invention is exercising a leveling influence in both moral and religious intercourse.

Then how very evident it is that engineering is not the befouling exhaust from the dynamic forces driving the social organization to its destined goal. Rather, it is the very engine itself, the central sun of a system energized by its radiated power. The profession is recruited from all ranks. The humble son of poverty and adversity may aspire to the contribution of something to what has already been done. He may gain a place in illustrious renown with Lord Kelvin or Sir Robert Hadfield.

The Dominion has furnished its share of men, eminent in the profession and distinguished for their intellectual and humanistic efforts. These men have made available the natural resources. Where water has offered a source of power, plants and machinery to utilize the energy have been devised. Uses have been sought for the power, resulting in the establishment of new enterprises. Means to carry this energy for long distances have been discovered. Where minerals have been stored in natural deposits, they have been made available by airplane, by railway, and by motor truck. The vast lumber resources and the grain of western provinces have both found an outlet to the world's markets. If waterways are needed, a Welland canal shows what can be provided. If open water is blocked by ice, interfering with navigation in winter, the engineer finds a way to break the icy grip and speed the vessel on its way. If the natural beauty of rugged regions, the piscatorial sport of inland rivers, the restful haunts of sylvan scenes call to the touring vacationist,

the roads have been prepared and sustenance made accessible.

If, in a rural community, an unusual event occurs and an unknown doctor ushers five little strangers out of the nowhere into the here, progress makes it possible to apprise an alert world; makes possible the demand for supplies to sustain and nourish, to reach the proper people; makes possible the delivery of these supplies without delay; makes possible a path whereby the curious may reach the nursery door; makes possible five happy, healthy sisters of equal age.

The world is narrowed, time abbreviated, and all the people made more intimately connected. If a king takes leave of his loving and beloved subjects, his voice is carried to their ears in every part of the vast empire. If a king is crowned, the coronation ceremony is pictured in the public prints almost before the tumult and the shouting have subsided. To the vast multitude of loyal souls who shout "Long Live the King," the newly crowned sovereign addresses his thoughts and bespeaks the patience, loyalty, and support every true leader of a people desires to have.

There are social ills and misfortunes which progress has not eradicated nor in any great measure corrected. They are inherent in individual differences, yet based on a rather universal human trait of acquisitiveness and self-seeking. The evidences are manifest in greed, antisocial attitude, dishonesty, and oppression. Individual traits, within limits, are modifiable and controllable no less than our social relations and institutions. The social-economic order may be changed by wisely guided imaginative construction and clearheaded cooperative action.

Many of our leading thinkers, and some of the best in the engineering field, have focused attention on these outstanding deficiencies of our social life. They have applied the same keen analytical powers to secure the proper perspective. The problem has been outlined, but the key to its solution is still lacking. The difficulties to be overcome and the obstacles to be surmounted are no more invincible than nature has presented to the engineer who has won the victory.

"The Next Fifty Years"

AT the Wednesday luncheon, C. D. Howe, honorary member of the Institute presiding, Harrison P. Eddy, of Boston, past-president of the American Society of Civil Engineers, was to have read an address, "The Next Fifty Years." Mr. Eddy's sudden death on Tuesday, while in attendance at the semicentennial, prevented his delivering the address in person.

Engineers in all fields who knew Mr. Eddy revered him for traits of nobility and courtesy that were fitting accompaniments to the dignity of his appearance, and respected him for the high quality of his achievements as a consulting engineer. To these friends especially this address to the Canadian engineers will recall the calm wisdom of Mr. Eddy that was born of a rich experience. If Mr. Eddy had planned a valedictory he could scarcely have done better. The more significant passages of the address are quoted in what follows.

In the fifty-year period before us there will be an accelerated advance in the accomplishments of engineering which, broadly speaking, is the application of science. New discoveries in science and their use by means of new inventions, will follow one another with ever-increasing rapidity. Often one discovery will reveal a score or more of new opportunities which speedily will be developed and made useful to man.

This acceleration in the speed of engineering advancement will be due in part to the increase in the number of workers in this field, made available through the competition of engineering colleges to gain students, and especially the growing conviction among parents, whether well-founded or not, that an engineering education carries with it an improved economic and social status. The public has become "engineering-minded."

A Forecast

No one can foretell with accuracy what specific results will ensue from this intensified development along engineering lines; but a few accomplishments are clearly evident:

Space, already so greatly reduced, will, practically speaking, be well-nigh eliminated by the conquest of the air.

Mass production will be extended to far more industries.

Agriculture will yield more and more to a combination of control and mechanization. With the aid of new methods of processing and the discovery of synthetic foods, the necessary agricultural products for a unit of population will be provided with a fraction of the labor and land now used.

Automatic control of production and operation will further greatly reduce the need for manual control.

New scientific discoveries, new sources of power, and the development of new processes and inventions will make necessities and many luxuries more generally available.

Such changes will inevitably shorten the work time required to satisfy the demands of the public. In Canada and the States it has been reduced one third during the last 50 years. Is it not probable that an equal reduction will result in the next 50 years? If so, the required work time will become only one-half what it is at present. Probably 20 hours a week is a conservative estimate.

Whatever this reduction may be, it will result largely from the activities of the engineer. Credit for lightening the human burden, however, will be accompanied by liability for any unfortunate results which may ensue and the public will look to the engineer to provide the means to avoid them.

The Problem of Leisure

One of the grestest problems which will be created by such changes and which even now is urgently demanding attention is, What shall we do with our released time and energy?

Some of the ill effects of a surplus of spare time already have become evident. Among a substantial number of persons there has apparently developed a lack of desire to work for the purpose of bettering their condition. To illustrate, it has recently been found so easy to do a minimum of work for a modicum of compensation, under the guise of relief, that the incentive to produce more for a greater reward has become atrophied. This tends toward a falling, not a rising, standard of living.

We are wont to believe that our modern civilization has produced a higher standard of living. Unless this great problem of the application of leisure time is judiciously solved, the undirected forces of human nature may reduce the present standard of living and wreck our civilization.

The most obvious and popular solution of the problem seems to be the development of recreation, and in the next 50 years games, sports, hunting, fishing, travel, and a long list of recreational pursuits will be brought within easy reach of more and more of the people. In providing such means the engineer will take a prominent part. New machines and equipment will be invented and used partly or exclusively for recreation; greater sums will be spent, for the most part under the technical direction of the engineer, on the development of highways, playgrounds, parks, and other recreational facilities. While this movement is valuable, is it to be the sole solution of the problem during the next 50 years? Can recreation take the place of work in providing training and discipline? Will the making available of so large a proportion of time for play result in producing a lack of respect for and obedience to law; will it diminish initiative and ambition? There certainly is grave doubt whether the solution can be found in recreation alone.

I foresee a longer period of education for youth, extending perhaps to the completion of a junior-college course, say at the age of twenty. This will provide a general education including opportunity for trade and vocational training, but it should not be continued too long, because youth is anxious to begin his life work; he is "champing at the bit," his ambition must not be permitted to wane.

In addition to this general education, post-scholastic study will become much more common and will provide both for entertainment and for the development of handicraft, science, the arts, and literature. It will continue through adult life. There will ensue a return of the craftsman, who will work for the pleasure of working and to produce useful and ornamental things in the making of which he will take a just pride. The pursuits of art and literature are appropriate home avocations. Study and research in the home are not impracticable, and for the more involved work laboratories open to the public could be provided.

The Professional Engineer of the Future

The professional engineer of the future will be more highly educated than in the past. His four-year college training will be devoted to the fundamental sciences with generous allowances for the liberal arts and humanities. His professional study will follow in what we now call "post graduate" years. He will then have a service period of several years before he will formally enter the profession. Only by such modifications of the present prevailing college training can the engineer of the next 50 years be adequately equipped.

Providing for the future, as his work necessitates, recognizing and applying the discoveries in science and appreciating that there is a vast realm of the unknown yet to be explored, from which new truths are still to be learned, the engineer must be progressive and at the same time sound; he must distinguish fallacies from truths. If he takes advantages of his opportunities during the next 50 years, the engineer will exert a greater influence upon the progress of civilization and the well-being of mankind.

The scope of our engineering societies must be broadened. They must maintain a high technical standard through interchange of the results of experience and research, as the Institute has so well done in the past, but they must also devote more time and energy to the study of economic, social, and governmental problems, both national and international.

S.P.E.E. Meets at Cambridge and Elects Officers for 1937–1938

M.I.T. and Harvard Act as Hosts for 1600

AT THE forty-fifth annual meeting of the Society for the Promotion of Engineering Education, held at the Massachusetts Institute of Technology and Harvard University, Cambridge, Mass., during the week of June 28, 1937, with an attendance of 1600, Samuel B. Earle, dean of engineering, Clemson Agricultural College, S. C., and nominee for managership, The American Society of Mechanical Engineers, was elected president for 1937–1938. Vice-presidents elected were Karl T. Compton, president, M.I.T., member A.S.M.E., and F. C. Bolton, dean, School of Engineering and of the College, A. and M. College of Texas. W. O. Wiley, of John Wiley and Sons, New York, N. Y., was reelected treasurer for a thirty-first term. F. L. Bishop, professor of physics, University of Pittsburgh, was reelected secretary.

Members of the council to serve a three-year term elected at the Cambridge meeting were: G. F. Eckhard, dean, College of Engineering, University of Vermont; S. C. Hollister, director, School of Civil Engineering, and associated dean, College of Engineering, Cornell University, member A.S.M.E.; F. M. Feiker, executive secretary, American Engineering Council, member A.S.M.E.; F. B. Seely, head of Department of Theoretical and Applied Mechanics, University of Illinois; A. H. White, professor of chemical engineering, University of Michigan; R. W. Sorensen, professor of electrical engineering, California Institute of Technology; and D. S. Elliott, professor of physics, Tulane University.

In addition to the officers already mentioned, R. E. Doherty, president, Carnegie Institute of Technology, Pittsburgh, Pa., was elected to succeed H. P. Hammond as S.P.E.E. representative on the Engineers' Council for Professional Development.

Division of Mechanical Engineering Meets

Regular sessions of the annual meeting which began on Wednesday, June 30, were preceded by sessions of the summer conference on mechanical engineering, under the auspices of the newly formed Division of Mechanical Engineering, and similar conferences on machine design, civil engineering, mechanics, chemical engineering, electrical engineering, English, and physics.

The Division of Mechanical Engineering adopted a plan of organization consisting of an executive committee and four subcommittees on manufacturing materials and processes, heat power, machine design, and management. Frank L. Eidmann, of Columbia University, member A.S.M.E., and F. D. Carvin, of the Newark College of Engineering, member, A.S.M.E., were elected chairman and secretary respectively of the division.

At the opening session of the conference on mechanical engineering, Frank L. Eidmann, presiding, J. C. Hunsaker, of M.I.T., member A.S.M.E., read a paper in which he traced changes in the curricula of mechanical engineering courses over the last 25 years. Geo. A. Orrok, consulting engineer of New York, honorary member, A.S.M.E., addressed the afternoon session on the aims and objectives of mechanical-engineering education. Mr. Orrok's paper appears on pages 591–594 of this issue.

A luncheon on Monday noon served as a reunion meeting of those who attended the 1928 Summer School for Teachers of Mechanical Engineering, at Purdue University. The Division's first annual dinner was held Monday evening, with C. E. Davies, secretary, A.S.M.E., acting as toastmaster. H. P. Hammond, president, S.P.E.E., F. L. Bishop, secretary, S.P.E.E., C. H. Berry, of Harvard University, member A.S.M.E., and H. P. Gough, of the National Physical Laboratory, London, England, spoke. Round-table discussions on the teaching of many phases of the mechanical-engineering curriculum followed the dinner.

Tuesday morning's session was held jointly with the Division of Machine Design. Reports of the round-table discussions of the previous evening were heard and A. A. Potter, past-president, A.S.M.E., read an able paper on "Factors Contributing to Effective Teaching of Mechanical Engineering. President Compton, of M.I.T., addressed the afternoon session on the subject, "Who Is a Good Teacher?" Drawing upon his wide personal experiences with teachers as student, teacher, and administrator, President Compton emphasized certain good and poor traits of teaching technique.

At the annual dinner of the S.P.E.E. held on Thursday evening at M.I.T., H. P. Hammond, president, presided.

The Lamme Medal for achievement in engineering education was presented to Frederick Eugene Turneaure, of the University of Wisconsin. The citation read:

The award of the "Lamme Medal" to Dean Turneaure is for his influence upon the policies and people of the College of Engineering of the University of Wisconsin; for his conception of a university as a cooperative enterprise of scholars and disciples in which freedom and power to initiate is diffused, not centralized; for the spirit of steadiness and confidence he has engendered; for the harmonious and cooperative relations within faculty and between faculty and students that have matured under his leadership; and in recognition of the high place he has filled in engineering education and in public estimation not only in his commonwealth but in the nation as well.

Henry M. Wriston, president, Brown University, delivered the principal address. He urged the necessity for more and better socially minded engineers.

The Engineering Teacher

H. P. Hammond's presidential address was entitled, "The Engineering Teacher." He dwelt on engineering teaching as a profession, the selection and development of teachers, the process of induction into teaching, learning to teach, and the qualities of a teacher. The concluding portion of his address dealt with the general nature of the social era in which the engineering teacher functions and the place he occupies in it.

The News From Washington

By American Engineering Council

March of Rural Electrification

RURAL electrification has increased from virtual stagnation during the depression to the highest peak in history. Without taking into consideration the new distribution lines constructed with federal financing, more new customers were connected to farm power lines in 1936 than in any other year since "electricity started to the country." Plans for 1937 indicate that privately financed lines will exceed 1936 and that the use of electrical energy in rural areas is "on its way."

A large part of the increase in the rural use of electricity is said to be due to the abandonment by utility companies of the practice of requiring farmers and rural industry to contribute to the cost of the lines which serve them. In many areas, distribution lines are being constructed to the consumers' property line without cash or deferred payment for such lines. Another contributing factor to the expansion is reported to be found in reductions in the cost of rural lines.

The Rural Electrification Administration reports that REA lines now equal privately financed lines. A recent summary states that a total of $61,112,110 has been lent or earmarked for 337 specific projects to serve about 200,000 rural customers in 41 states. A majority of the consumers are farmers, but the total includes a great many rural schools, churches, small business establishments in rural areas, and country homes. $1,925,000 of the total has been allotted for building small generating plants, and $190,000 has been borrowed by individuals to finance wiring and plumbing installations.

Plans and specifications prepared by engineers in private practice and approved by the engineering staff of REA are required on all projects, and the American Engineering Coun-

cil is frequently called upon to suggest candidates for engineering positions in Washington and in the states. The compensation either by fee or salary is not always in keeping with that paid by private industry, but the engineering profession is being permitted to make its contribution to public as well as private rural electrification, and the appreciation of the value of engineering knowledge and experience is increasing and spreading to the less populated areas.

Mapping a Local Responsibility

A "MAP Consciousness" has been carried to the White House and to Congress, but it has not yet become sufficiently important in the several states and communities to command the serious consideration of those who are in a position to inaugurate a comprehensive mapping program. Council's staff, the A.E.C. Committee on Surveys and Maps Program, the Division of Surveying and Mapping of A.S.C.E., and many of those who recognize the fundamental need for accurate maps and appreciate the economic value of such basic data to the public have done almost everything *except* lobby for substantial mapping appropriations.

The President, the Congress, departmental secretaries, bureau chiefs, and most officials and representatives of the people are responsive to factual presentation and they are being kept informed, but obviously a demand from "the constituency" for maps for both immediate and future use is essential to favorable legislative action. It is not enough to have engineers, planners, geologists, and other scientific and constructive minds in favor of making surveys and preparing basic maps of the terrain of the United States. The people themselves must insist upon having maps for public works and private enterprise.

A number of federal government agencies, other than U.S.C. & G.S. and U.S.G.S. are making "special purpose" maps. Most of them are good maps, but they are not basic and many of them cannot be fitted into a nation-wide basic mapping program. It is reported that the Soil Conservation Service, for example, is to do some 350,000 sq miles of aerial mapping in 1937 and 1938. No one has any doubt about the usefulness of such maps to all parties interested in soil conservation, but it is not expected that they can be used either by the Coast and Geodetic Survey on triangulation or by the U. S. Geological Survey for reckoning topography.

Engineers who have made a lifelong study of map making and map uses agree that if the triangulation and topography of the country were established on verified maps which were accurately related, it would not be necessary to make so many maps for special purposes. They also agree that the cost of making special maps, when actually needed, would be greatly reduced by having basic triangulation and topography as a foundation.

Such are the simple facts which engineers may impart to their neighbors, business associates, and legislative representatives. They may also say, without fear of contradiction, that the Army needs more of this basic information around our frontier to strengthen national defense. The Forest Service, Reclamation Service, Soil Conservation Service—all of those interested in regional conservation activities, and innumerable private projects are constantly faced with need for better maps than are available, and find from actual experience that much more could be saved by having adequate maps than the entire cost would be.

National Resources Committee

ENGINEERS who have noted the proposals made by the Administration and members of Congress to reorganize the surface of the United States into seven conservation and utilization authorities may be interested in the following excerpts from recent reports of the National Resources Committee:

Prepared under the supervision of the Water Resources Committee of the National Resources Committee, the present report, "Drainage Basin Problems and Programs," describes the principal water problems of each of the drainage basins and presents specific recommendations for construction and investigation projects with priorities of importance and time. The report was prepared with the active cooperation of state and regional planning boards and of federal agencies. Three principal aspects emphasized in connection with the program are:

(1) That the report does not suggest any particular rate of public construction expenditure. It suggests an orderly integrated plan of construction and investigation, which may be carried out over a period of years.

(2) That the listing of projects having local interest primarily does not indicate that federal funds should be used for their construction. The listing means only that the project is believed to fit into an integrated drainage basin program.

(3) That the National Resources Committee will not be responsible for carrying out any of the recommended work; it is not an administrative agency. The work suggested, if carried out, will be through the normal channels of existing federal, state, and local agencies. The report is based on an intensive study by a special organization established by the Water Resources Committee, which worked in close cooperation with state planning boards as well as with all federal agencies concerned with water problems.

Projects are classified into the following groups: Group *A* is ready for construction and should be undertaken as soon as possible. Group *B* while desirable can have priority definitely determined only after additional studies. Group *C* should follow group *B* in sequence. The estimated cost of the project in group *A* is $1,727,000,000 in group *B* $1,034,000,000, and in group *C*, $1,400,000,000.

An interesting comparison may be had by noting that the annual federal expenditures for construction involving water use and control in the period from 1920 to 1929 range from 30 to 63 million dollars and only increased to 78 million in 1929, whereas they had reached a figure of 374 million dollars by 1935. It would, therefore, seem that the proposed reservoir of projects in groups *A*, *B*, and *C* for a period of years for both federal and nonfederal undertakings in the field of water control and use, which would be left subject to review and control in the future, is more consistent with the normal rate of expenditures for such purposes in this country.

Survey of Engineers and Engineering

THE excellent work done by the American Engineering Council's Committee on the Survey of Engineers and Engineering continues to be reflected in the series of bulletins which are being released by the Bureau of Labor Statistics. The first release entitled "Educational Qualifications in the Engineering Profession" was about a year ago. The second release came in January under the title "Unemployment in the Engineering Profession." A third release entitled "Employment in the Engineering Profession from 1929 to 1934" came out a few weeks ago.

One of the most important phases of this analysis indicates that, taking all factors into consideration, between 1930 and 1934 there was a substantial net loss of employment by engineers who were active before 1935 and a considerable absorption in employment of newcomers to the profession. The net result for the five-year period ending December, 1934, was an increase of 25.3 per cent in the number of persons in the engineering profession. This rate of increase was much in excess of the available engineering opportunities. The fact that available engineering opportunities did not keep pace with the increase in the number of men trained to enter the profession brought about changes in the proportions of those who were unemployed or engaged in nonengineering work.

The analysis entitled "Employment in the Engineering Profession" appeared in the April issue of the *Monthly Labor Review*. A limited number of copies are in the hands of the Bureau of Labor Statistics and may be obtained by writing to Dr. Isador Lubin, Commissioner, Bureau of Labor Statistics, Department of Labor, Washington, D. C. In the event that a large number of copies is desired, they may be obtained, as long as they last, from the United States Government Printing Office.

Conservation of River Resources

SINCE A.E.C. Committees on flood control, water resources, and other conservation activities have for a number of years recommended consideration of the problems involved according to drainage areas as a whole, the basic idea back of the President's recommendation that the United States be divided into seven regions is in keeping with the Council's earlier interpretations of engineers' recom-

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Again . .

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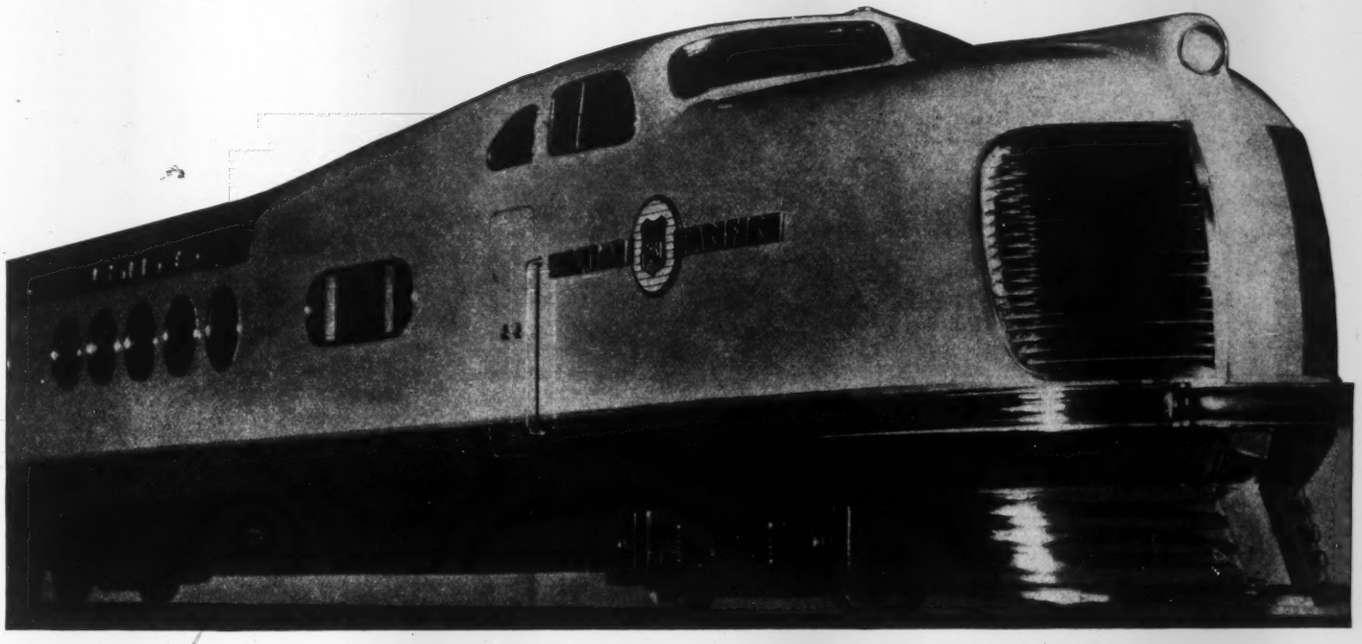

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mendations. It is also in line with the suggestions offered by a number of prominent engineers about a year ago in connection with discussions of the program of the Upstream Engineering Conference.

It is encouraging to observe in the President's recent river-conservation message that the protection of the country's water resources is at last receiving authoritative recognition, but it is unfortunate that matters of such vital importance should be confused with other issues. As was to be expected, some elements in Congress are seizing upon the President's message as an opportunity to promote their desire for increased public power development and more federalization. It seems as though they are even willing to sacrifice the real conservation and reclamation values. Others, more moderate in their views, lean toward the establishment of regional-planning commissions in accordance with the President's recommendations. In this difference of ideas is to be found a most vital issue in the future social and economic life of our country.

The experience of recent years shows that we know too little about rivers for any comprehensive planning on such a scale without much study and more data. Engineers on the Council's committees feel that we have not yet learned enough about regional planning to undertake the development and conservation planning for the scores of streams involved in the seven proposed authorities. It is true that the National Resources Committee has only recently completed a drainage-basin survey, but the very engineers who made that survey say that it is only a preliminary for a further investigation.

Realizing that we face urgent problems of conservation, of water allocation, of purification, of floods, of water supply, and in a lesser degree of power and navigation, it is believed that the most practical approach to these problems may be made through boards set up to deal with each river basin as a whole. A board of local membership should be able to accomplish useful results at an early date. Its work could be coordinated with regional activities and given businesslike attention.

Council's Committee on the Conservation and Utilization of Natural Resources is giving this entire problem serious consideration.

World Power Conference

ONE of the objectives of the World Power Conference is the preparation of inventories of the resources of the world in fuel and power. The first inventory entitled "Statistical Yearbook of the World Power Conference," now ready for distribution, represents an excellent attempt to compile and publish international statistics of power resources, development, and utilization upon a comprehensive and comparable basis. Some of the information has not been published before in any country. As a collection of statistics on this particular subject, the work is probably unique and for this reason may prove most valuable to those interested in the development of world power resources.

Engineers, economists, statisticians, and others who require such information as comparable figures of coal consumed in the U.S.A. and the U.S.S.R., or of electricity generated in metallurgical works in Poland and Japan, or estimates of the world production of petroleum or wood, or the proportion of electricity generated by water power will find much of the information which was available in 1933 and 1934 in this compact volume which is being sold at $5 per copy by the American National Committee, World Power Conference, Interior Building, Washington, D. C.

Positions Available

Engineering Societies Employment Service

ENGINEER to work out efficient layout of factory for manufacture of ball bearings. Will help select and supervise installation of necessary machinery. May eventually become factory manager. Apply by letter. Location, foreign. Y-1625.

ENGINEER to act as chief assistant. Must have experience in hydraulic and flood-control work. Salary, $5000 a year. Apply by letter. Location, East. Y-1764.

EXECUTIVE to take charge of management and production of jobbing business. Must have experience in metal trades and in handling labor. Apply by letter. Location, Massachusetts. Y-1785.

DESIGNER, mechanical engineer, 30–40, for automobile tires. Must be expert draftsman with tire-designing experience, with ability to establish contacts with major executives and producing department heads. Salary, $350–$500 a month. Apply by letter. Location, Middle West. Y-1794-C.

ENGINEER, 30–40, thoroughly experienced in automobile-tire development and design. Must have ability to establish contacts with major executives and producing department heads. Should have chemical experience, sales personality, and practical mind. Salary, $400–$600 a month. Apply by letter. Location, Middle West. Y-1795-C.

MECHANICAL ENGINEERS to become general foreman, superintendents, and product engineers. Necessary to start in other positions in organization to acquire knowledge of local conditions essential to supervisory positions. Company manufactures hardware for automobile bodies, including large stampings, die castings, plating, graining and lacquering. Apply by letter. Location, Middle West. Y-1643-C.

METALLURGIST for creative work of diversified character in research department. Must be metallurgist with graduate training or physicist with strong leaning toward metallurgical problems. In either event must have philosophical and inquiring trend of mind, capable of handling new research problems. Apply by letter. Location, East. Y-1644.

CHIEF DIE DESIGNER, 35–47, to take charge of die-design work. Must be thoroughly experienced in designing of small, intricate, interchangeable dies used in quantity production. Graduate engineer preferred, though more essential that man have actual die-making experience and ability to become successful die designer. Salary, $300 a month to start. Apply by letter. Location, East. Y-1656.

PLANT-OPERATING SUPERINTENDENT, 35–50, for company employing 75 persons and manufacturing insulating board with thermal and acoustical properties. Must have technical background, predominating mechanical practice but with some chemical knowledge. Experience in manufacture of building, wall, or insulating board would be helpful. Salary, $4000–$6000 a year. Apply by letter. Location, Middle West. Y-1880-C.

ESTIMATOR with 10–12 years' experience in refining or related work. Must have real knowledge refinery-equipment estimating. Apply by letter. Location, New York. Y-519.

SALES ENGINEER, young, to sell stokers. Must have technical training in mechanical engineering or practical experience in combustion, and knowledge of power plants and multiple-retort stokers, obtained from practical experience or sales work. Sales experience desirable. Apply by letter giving details of experience, salary expected, age, etc. Location, Middle West, Y-1792-C.

SHOP FOREMAN, mechanical engineer, not over 45, for plant manufacturing combustion engines. Experience in this line desirable. Will start as trouble shooter, solving troubles of each particular machine and checking work from operation to operation. Later will assume control of shop. Salary to start, $60–$65 a week. Apply by letter. Location, East. Y-1698.

TIME-STUDY ENGINEER capable of setting up standard data. Must have experience in light, highly repetitive manufacturing processes, and working knowledge of tool and die design or manufacture. Apply by letter. Location, Pennsylvania. Y-1875.

ASSISTANT SUPERINTENDENT, 35–40, for rubber department of large company handling packing and brake blocks. Technical rubber man, capable of handling men and adjusting production to diversity of large and small orders. Salary, $350 a month. Apply by letter. Location, Illinois. Y-1803—R-566-C.

MECHANICAL ENGINEER, graduate of university of recognized standing, with several years' experience. Should know machine design and something about electricity, heating, power, air conditioning, repair, and mainte-

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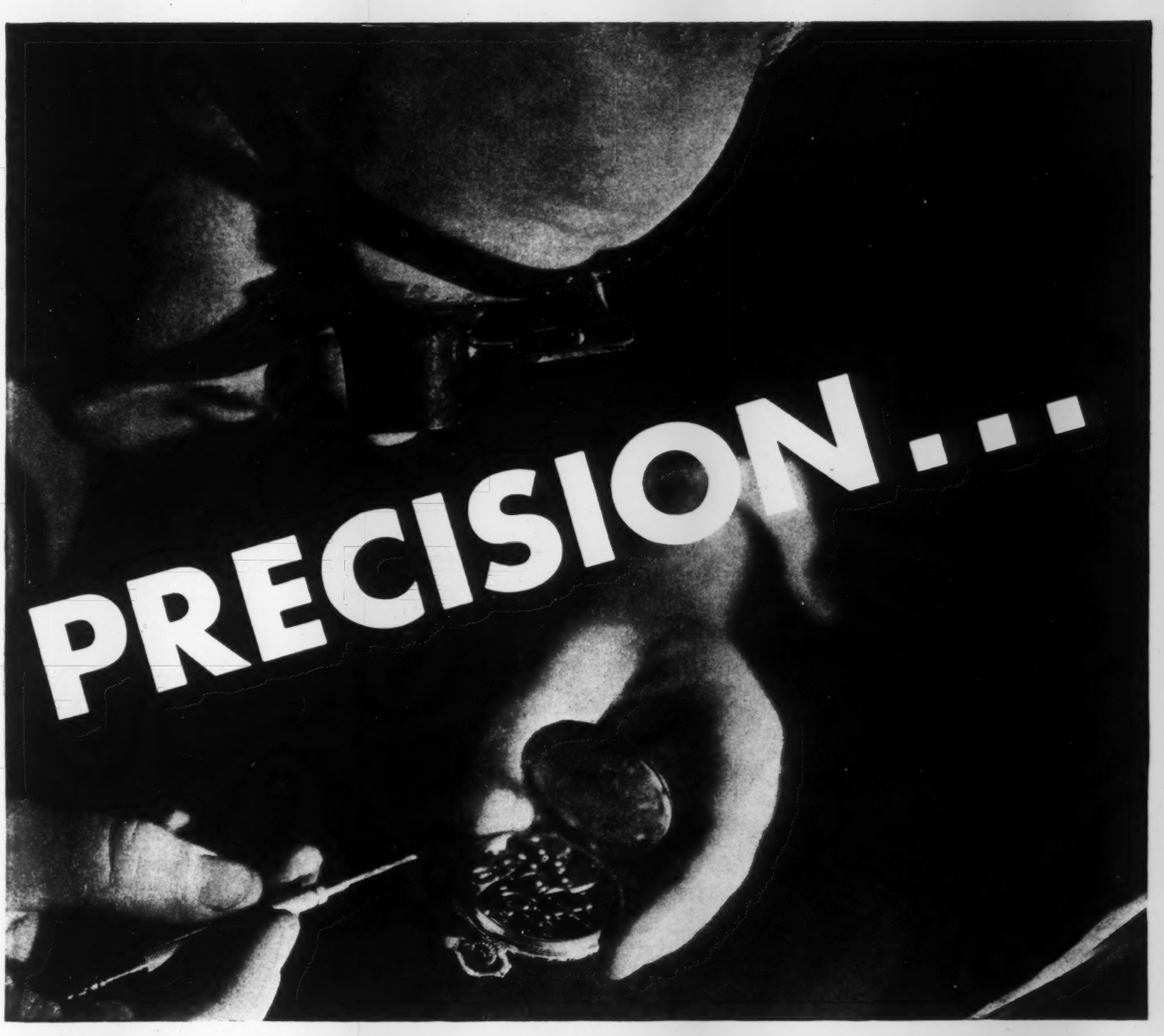

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